

NATIONAL WATER-QUALITY ASSESSMENT PROGRAM

Water-Quality Assessment of the Eastern Iowa Basins: Selected Pesticides and Pesticide Degradates in Streams, 1996–98

Water-Resources Investigations Report 03–4075



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Top, photograph of a corn field in late spring from a farm near Riverside, Iowa
(photograph by Doug Schnoebelen, U.S. Geological Survey)
Middle, aerial photograph of farms in east-central Iowa
(photograph by Steve Kalkhoff, U.S. Geological Survey)
Bottom, aerial photograph of the Cedar River as it flows through Cedar Rapids, Iowa
(photograph by Steve Kalkhoff, U.S. Geological Survey)

FOREWORD

The U.S. Geological Survey (USGS) is committed to serve the Nation with accurate and timely scientific information that helps enhance and protect the overall quality of life, and facilitates effective management of water, biological, energy, and mineral resources. (<http://www.usgs.gov/>). Information on the quality of the Nation's water resources is of critical interest to the USGS because it is so integrally linked to the long-term availability of water that is clean and safe for drinking and recreation and that is suitable for industry, irrigation, and habitat for fish and wildlife. Escalating population growth and increasing demands for the multiple water uses make water availability, now measured in terms of quantity *and* quality, even more critical to the long-term sustainability of our communities and ecosystems.

The USGS implemented the National Water-Quality Assessment (NAWQA) Program to support national, regional, and local information needs and decisions related to water-quality management and policy. (<http://water.usgs.gov/nawqa>). Shaped by and coordinated with ongoing efforts of other Federal, State, and local agencies, the NAWQA Program is designed to answer: What is the condition of our Nation's streams and ground water? How are the conditions changing over time? How do natural features and human activities affect the quality of streams and ground water, and where are those effects most pronounced? By combining information on water chemistry, physical characteristics, stream habitat, and aquatic life, the NAWQA Program aims to provide science-based insights for current and emerging water issues and priorities. NAWQA results can contribute to informed decisions that result in practical and effective water-resource management and strategies that protect and restore water quality.

Since 1991, the NAWQA Program has implemented interdisciplinary assessments in more than 50 of the Nation's most important river basins and aquifers, referred to as Study Units. (<http://water.usgs.gov/nawqa/nawqamap.html>). Collectively, these Study Units account for more than 60 percent of the overall water use and population served by public water supply, and are representative of the Nation's major hydrologic landscapes, priority ecological resources, and agricultural, urban, and natural sources of contamination.

Each assessment is guided by a nationally consistent study design and methods of sampling and analysis. The assessments thereby build local knowledge about water-quality issues and trends in a particular stream or aquifer while providing an understanding of how and why water quality varies regionally and nationally. The consistent, multi-scale approach helps to determine if certain types of water-quality issues are isolated or pervasive, and allows direct comparisons of how human activities and natural processes affect water quality and ecological health in the Nation's diverse geographic and environmental settings. Comprehensive assessments on pesticides, nutrients, volatile organic compounds, trace metals, and aquatic ecology are developed at the national scale through comparative analysis of the Study-Unit findings. (<http://water.usgs.gov/nawqa/natsyn.html>).

The USGS places high value on the communication and dissemination of credible, timely, and relevant science so that the most recent and available knowledge about water resources can be applied in management and policy decisions. We hope this NAWQA publication will provide you the needed insights and information to meet your needs, and thereby foster increased awareness and involvement in the protection and restoration of our Nation's waters.

The NAWQA Program recognizes that a national assessment by a single program cannot address all water-resource issues of interest. External coordination at all levels is critical for a fully integrated understanding of watersheds and for cost-effective management, regulation, and conservation of our Nation's water resources. The Program, therefore, depends extensively on the advice, cooperation, and information from other Federal, State, interstate, Tribal, and local agencies, non-government organizations, industry, academia, and other stakeholder groups. The assistance and suggestions of all are greatly appreciated.

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By Douglas J. Schnoebelen, Stephen J. Kalkhoff, Kent D. Becher,
and E.M. Thurman

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To obtain
Length		
centimeter (cm)	0.03937	inch
meter (m)	3.281	foot
kilometer (km)	0.6214	mile
Area		
cubic hectometer (hm ³)	810.7	acre-foot
hectare	2.471	acre
square kilometer (km ²)	0.3861	square mile
Flow		
cubic meter per second (m ³ /s)	35.31	cubic foot per second
Concentration		
micrograms per liter (µg/L)	1.0	parts per billion

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$^{\circ}\text{F} = (1.8 \times ^{\circ}\text{C}) + 32$$

Concentrations of chemical constituents in water are given in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Water year is the 12-month period from October 1 through September 30 and is designated by the year in which it ends. For example, the water year ending September 30, 1996, is called water year 1996.

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Abstract

Water samples were collected in streams of the Eastern Iowa Basins study unit from 1996 to 1998 as part of the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program. More than 350 samples were collected to document the occurrence, distribution, and transport of pesticides and pesticide degradates. The Eastern Iowa Basins study unit encompasses about 50,500 square kilometers (19,500 square miles) in eastern Iowa and southern Minnesota and is drained by four major rivers—the Wapsipinicon, Cedar, Iowa, and Skunk—which flow into the Mississippi River at the eastern border of Iowa.

The most commonly detected pesticides—acetochlor, alachlor, atrazine, cyanazine, and metolachlor—were those most heavily used on crops during the study. Atrazine and metolachlor were detected in 100 percent, and acetochlor, alachlor and cyanazine were detected in more than 70 percent of all surface-water samples. Four pesticide degradates—metolachlor ethane sulfonic acid, alachlor ethane sulfonic acid, metolachlor oxanilic acid, and acetochlor ethane sulfonic acid were detected in more than 75 percent of the samples. Only one nonagricultural herbicide, prometon, was detected in more than 80 percent of the samples. Carbofuran, the most commonly detected insecticide, was found in 16 percent of all samples.

Mixtures of pesticide compounds commonly occurred in the samples. Five or more parent pesticide compounds were detected in 50 percent of the samples. Four or more pesticide

degradates were detected in 68 percent and seven or more pesticide degradates were detected in 17 percent of the samples.

Acetochlor, alachlor, atrazine, cyanazine, and metolachlor were generally present at low concentrations; median concentrations ranged from 0.01 to 0.22 microgram per liter. However, median concentrations for the pesticide degradates, 0.07 to 3.7 micrograms per liter, were larger than their parent compounds. Acetochlor, alachlor, atrazine, cyanazine, and metolachlor pesticide compounds were detected at an order of magnitude or higher in the late spring and summer than at other times of the year.

Pesticide concentrations generally peak following application in May and June and decrease during the growing season. A small secondary peak of atrazine, acetochlor, alachlor, cyanazine, and metolachlor concentrations occurred in late winter at all sites. The seasonal patterns for the triazine (atrazine and cyanazine) degradates were similar to the parent compounds (increasing in the spring), but the triazine degradates often had higher median concentrations than their parent compounds in the fall and winter. The chloroacetanilide (acetochlor, alachlor, and metolachlor) degradates did not follow a strong seasonal pattern like their parent compounds. In general, the chloroacetanilide degradates had constant and higher median concentrations when compared to their parent compounds throughout the year. The median concentrations for the chloroacetanilide pesticide degradates were often an order of magnitude higher than their parent compounds.

Concentrations of pesticides varied by land-form region. Atrazine and cyanazine and their degradates were present in significantly greater concentrations in streams of the Southern Iowa Drift Plain than streams of either the Des Moines Lobe or the Iowan Surface.

INTRODUCTION

The occurrence, fate, and transport of pesticide and pesticide degradate compounds in surface water are an important component of water quality in the Eastern Iowa Basins (EIWA) study unit of the U.S. Geological Survey (USGS) National Water-Quality Assessment Program (NAWQA). Pesticides used to control weeds, insects, and other pests often receive widespread public attention because of their potential impacts on humans or the environment. Pesticides and their breakdown transformation products (degradates) are transported primarily by water from areas where they are applied to nearby rivers and streams. However, one of the largest gaps in Iowa's surface-water-quality data base is a lack of historical data on concentrations of pesticides in Iowa surface water (Iowa Department of Natural Resources, 1997, section 2, p. 47). Pesticides including herbicides, fungicides, and insecticides are used extensively in agricultural and urban settings in the EIWA study unit. The EIWA study is intended to provide much needed information on (1) the spatial and seasonal variability of pesticide and pesticide degradate concentrations and (2) natural and anthropogenic factors that may affect the fate and transport of pesticides in Iowa and in similar agricultural settings across the Midwest.

In 1991, the USGS began implementation of the NAWQA Program. The long-term goals of the NAWQA Program are to describe the current water-quality conditions and trends of the Nation's water resources and to link assessment with an understanding of the natural and human factors that affect the quality of water (Gilliom and others, 1995). The EIWA study unit encompasses about 50,500 km² (19,500 square miles) and is one of 15 NAWQA study units (Kalkhoff, 1994) that were selected nationally to begin assessment in 1994.

In Iowa, and across much of the Midwest, the occurrence, distribution, transport, and fate of pesticides in surface water are water-quality topics of

concern (Goolsby and others, 1991; Goolsby and Battaglin, 1993; Kalkhoff, 1993; Iowa Department of Natural Resources, 1994a; Hallberg and others, 1996). Common herbicides used in Iowa, such as atrazine, alachlor, and cynazine, are potential carcinogens and have Maximum Contaminant Levels (MCLs) established by the U.S. Environmental Protection Agency (USEPA) for drinking water (U.S. Environmental Protection Agency, 1995). Several pesticide degradates have been detected in surface waters of Iowa and the Midwest and can persist much longer than the parent compounds (Goolsby and Battaglin, 1993; Kalkhoff and others, 1998). Little is known about the occurrence of many pesticide degradates, and even less is known about their effects on human health and aquatic life (U.S. Geological Survey, 1999, p. 77). Several studies have raised additional concerns about potential effects of manmade chemicals in surface water on the endocrine systems of aquatic and terrestrial organisms (Colborn and Clement, 1992; Colborn and others, 1993; Goodbred and others, 1997). Concentrations of pesticides are typically highest in streams draining agricultural regions and water samples from these streams almost always contain at least one pesticide compound (Gilliom and others, 1999).

Surface waters are particularly vulnerable to contamination by pesticides because most agricultural and urban areas drain into surface-water systems. In particular, pesticides are commonly used on agricultural land and some agriculturally related practices such as tile drainage and cropping close to stream-banks can cause increased susceptibility to pesticide transport. Long-term monitoring of pesticides and pesticide degradates is needed to better understand the occurrence, transport, and fate of pesticides and pesticide degradates in surface water.

Purpose and Scope

This report summarizes results from selected pesticide and pesticide degradate analyses from samples collected from streams and rivers in the EIWA study unit for 1996–98. Results include (1) seasonal and spatial variability of pesticide and pesticide degradate concentrations and loads and (2) natural and human factors that may affect the fate and transport of pesticides in the Eastern Iowa Basins. Twelve sites on streams draining 320 to 32,400 km² were sampled for

pesticides and pesticide degradates monthly during the study. In addition, 25 sites on streams draining 310–1,500 km² watersheds were sampled for selected pesticides and pesticide degradates during base-flow conditions in August 1997 and May 1998 to better define spatial variability in the study unit.

DESCRIPTION OF THE EASTERN IOWA BASINS

The EIWA study unit encompasses the Wapsipinicon, Cedar, Iowa, and Skunk River Basins, which cover about 50,500 km² (19,500 mi²) of eastern Iowa and southeastern Minnesota (fig. 1). The four major rivers have their headwaters in the northwestern part of the study unit, flow southeastward, and discharge to the Mississippi River. Important components in the interpretation of the pesticide and pesticide degradate data include the geomorphology, climate, streamflow, land use, and types of pesticides used in the EIWA study unit.

Geomorphology

The EIWA study unit consists of three major landform regions (Des Moines Lobe, Iowan Surface, Southern Iowa Drift Plain) (Prior, 1991) and one subregion (Iowan Karst, a subregion of the Iowan Surface) that have distinct spatial differences in topography, geology, and soils (fig. 1). These regions also broadly coincide with ecoregions and subcoregions of Iowa (Griffith and others, 1994).

The Des Moines Lobe, in the western part of the study unit, is one of the youngest landforms in Iowa and is characterized by low local relief (15–30 m) and small slope (fig. 2). The Des Moines Lobe was formed approximately 12,000 to 14,000 years ago (Wisconsinan age) during the last glaciation in Iowa and has been only slightly altered since that time (Prior, 1991). The sediments of the Des Moines Lobe have not been exposed to erosion and weathering processes for as long a period of time when compared to sediments of the other older landform regions in the EIWA study unit. The topography consists of predominantly flat and slightly rolling land broken by curved bands of “knob and kettle” terrain (Buchmiller and others, 1985). Originally, ponds and wetlands were characteristic of the Des Moines Lobe. Extensive ditching and tiling of fields beginning in the early 1900’s has

increased the surface drainage in this area. The potential natural vegetation is bluestem prairie (Griffith and others, 1994), although corn and soybean production presently dominates. Stream development is poor with many small, low-gradient streams that drain into relatively few large rivers. Surficial material consists of loamy till that has an average thickness of approximately 30 m and alluvium in association with large streams. Surficial loess is absent.

The Iowan Surface is characterized by gently rolling topography with long slopes and low local relief (15–30 m) and small slope (fig. 2). Drainage is well developed although streams generally have small gradients. Surficial material consists of pre-Illinoian-age (500,000–700,000 years old) loamy till covered by a thin veneer of windblown loess on the ridges and alluvium near the streams (Prior, 1991). Potential natural vegetation is bluestem prairie and oak-hickory forest, although corn and soybean production presently dominates (Prior, 1991; Griffith and others, 1994).

The Iowan Karst is a subregion of the Iowan Surface where dissolution of soluble limestone and dolomite under cover of glacial drift has caused localized collapse of the land surface that resulted in a karst topography with numerous sinkholes. The surface drainage is well developed, and direct flow into bedrock units is common. This area is extensively used for agriculture and some fields are drained through agricultural drainage wells, which are a form of gravity-operated injection well. Field tile lines are typically connected to these drainage wells. The drainage wells and sinkholes can provide a conduit for surface runoff and field drainage to the underlying bedrock aquifer.

The Southern Iowa Drift Plain is characterized by steeply rolling terrain with moderate local relief (30–90 m) separated by flat, tabular divides (fig. 2). Surficial material consists of pre-Illinoian-age glacial deposits mantled by loess. Soils on the lower slopes commonly are derived from till, whereas soils on the higher slopes and upland flats are derived from loess. The steeper slopes and loess of the Southern Iowa Drift Plain are conducive to erosion and increased sediment transport to streams. Alluvium is present in association with streams that form a well-developed drainage pattern. Potential natural vegetation is bluestem prairie and oak-hickory forest (Griffith and others, 1994), although corn and soybean production presently predominates.

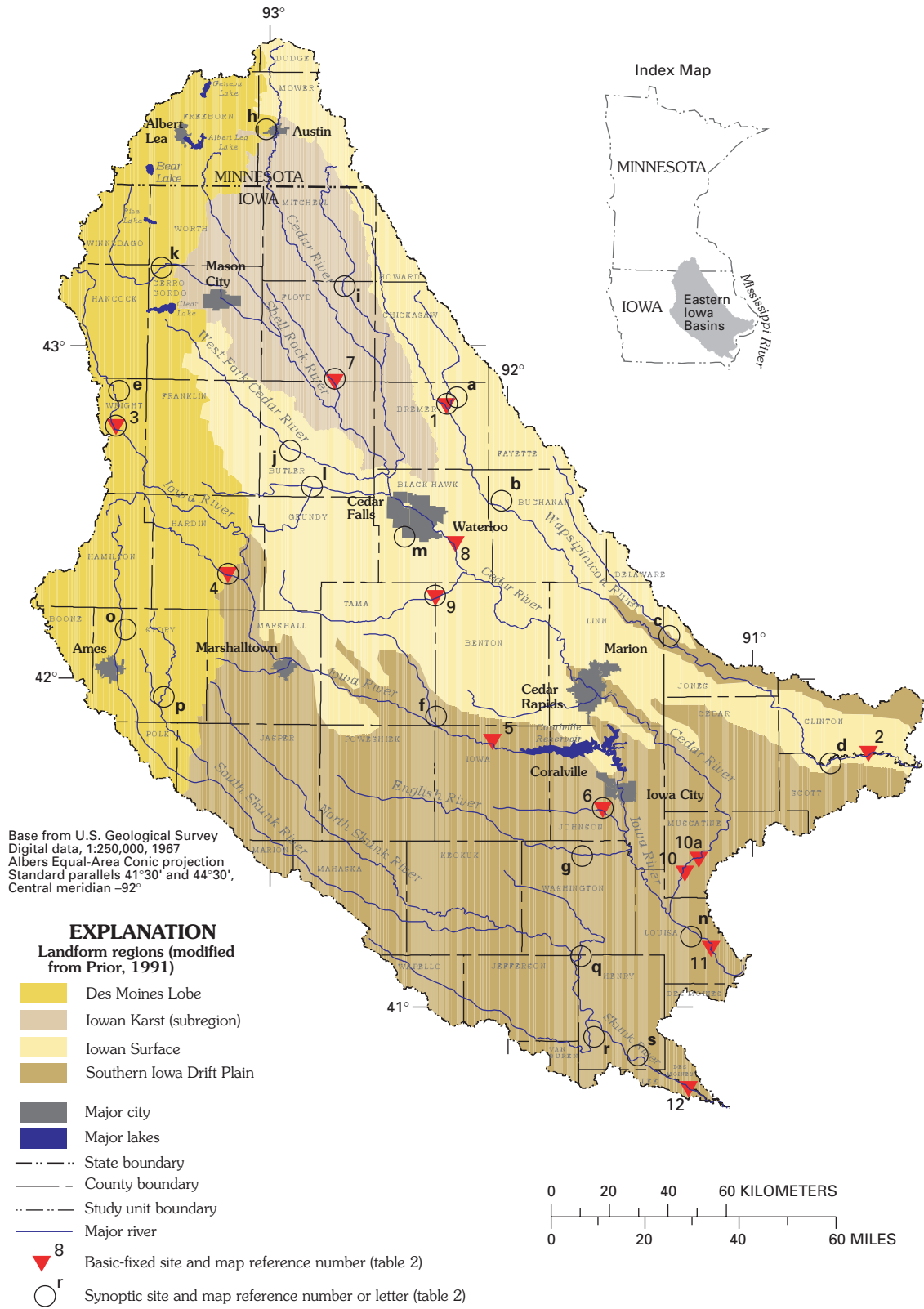
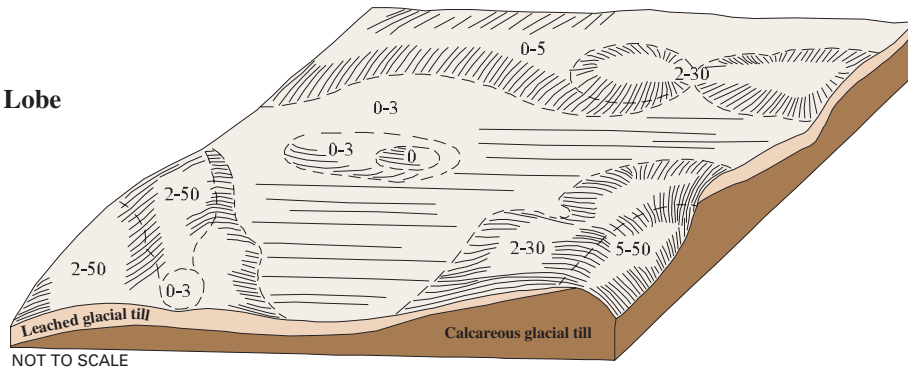
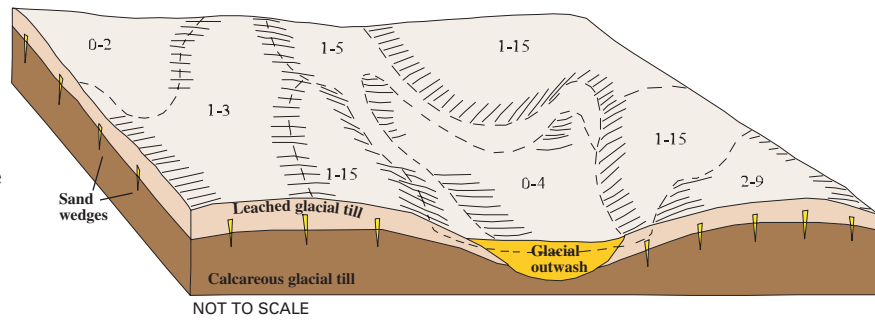


Figure 1. Landform regions and surface-water-quality sampling sites in the Eastern Iowa Basins study unit.

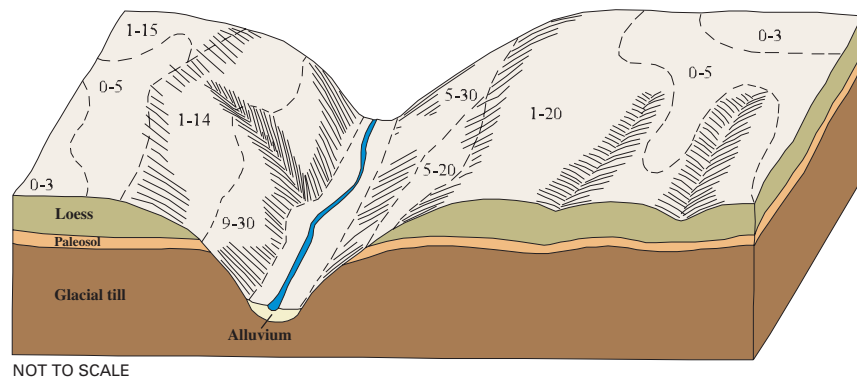
Des Moines Lobe



Iowan Surface



Southern Iowa Drift Plain



EXPLANATION

9-30 SLOPE—Numbers indicate ranges in slope, in percent

Figure 2. Physiography of landform regions in the Eastern Iowa Basins study unit (modified from Oswald and others, 1965).

Climate

The climate in the study unit is continental, with large differences in seasonal temperatures that result in distinct winter and summer seasons. Primary climatic effects in the EIWA study unit are warm, moist air from the Gulf of Mexico and surges of cold, dry air from Canada, which predominate in the summer and winter, respectively (U.S. Department of Commerce, 1959). Mean monthly temperatures range from -16°C for the lows in January to 28°C for the highs in July (Wendland and others, 1992). The growing season (generally April–September) lasts about 127 days and is characterized by mean temperatures of 19°C in the southern part of the EIWA study unit to 16°C in the northern part.

Precipitation occurs mostly as rain associated with thunderstorms that occur from April through September. About 71 percent of the annual rainfall occurs during this period (Harry Hillaker, Iowa Department of Agriculture and Land Stewardship, oral commun., 2000). The mean annual precipitation ranges from 76 cm in the northern part to 94 cm in the southeastern part of the study unit (Wendland and others, 1992). Peak precipitation occurs in June when crop-moisture demands are at their greatest and diminishes sharply during the fall harvesting season. Precipitation during the cooler months of the year generally is of long duration and of moderate or low intensity, whereas precipitation during the late spring and summer tends to be of shorter duration and of higher intensity. Large runoff events generally occur during the spring. Snow can remain on the ground through the winter (December through February) though there are typically days of “winter thaw” with some runoff of meltwater over partially frozen ground.

The seasonal timing of precipitation is an important factor in stream-water quality, especially streams affected by nonpoint sources (such as agricultural runoff). For example, heavy precipitation in May or June following application of pesticides will allow more pesticides to be transported to streams than if this same amount of precipitation occurred in the fall or winter seasons. In addition, during wet periods, ground-water levels can rise and sustain tile-drain flow, potentially causing transport of chemical constituents from the subsurface to streams.

Streamflow

Overland flow (direct surface runoff) and ground-water discharge are the major sources of streamflow in the Eastern Iowa Basins. Another source of flow to streams is interflow. Interflow is that part of the subsurface flow that moves at shallow depths and reaches the surface channels in a relatively short period of time and therefore is commonly considered part of overland flow. During a storm period, interflow slowly increases until the end of the storm period, then gradually decreases (Viessman and others, 1989, p. 171). Field tile drains can enhance the subsurface drainage component of flow to streams. In the study unit, the mean annual runoff (overland flow, ground-water discharge, and interflow) to streams (water years 1951–80) averages about 25 percent of the annual precipitation and increases from less than 15 cm in the western part of the study unit to more than 23 cm in the southeastern part (Gebert and others, 1987). Total mean annual streamflow from the study unit (based on the entire period of record available) averages about $11,340 \text{ hm}^3$ (9.2 million acre-ft) (Kalkhoff, 1994). The mean annual streamflow from the Wapsipinicon River Basin, the combined Iowa and Cedar River Basins, and the Skunk River Basin averages about 1,360, 7,770, and $2,220 \text{ hm}^3$ (1.1, 6.3, and 1.8 million acre-ft) respectively.

Precipitation and, in particular, spring rains in the Eastern Iowa Basins varied during the period of study. In 1996, the months of May and June were wetter than normal and the median streamflow was slightly higher than the historical middle 50 percent of discharge (fig. 3). In contrast, median streamflow in June 1997 was generally lower than the middle 50 percent (25th to 75th percentile) of historical streamflow reflecting fewer large rain events during 1997 (fig. 3). The median streamflow for June 1998 was higher than the middle 50 percent of historical streamflow and remained high for most of 1998 (fig. 3).

Land Use

Abundant rainfall, flat topography, and fertile soils in the Eastern Iowa Basins produce conditions ideal for agricultural production of corn and soybeans. Agriculture (row crops, pasture, hay, and small grain) accounts for 92.9 percent of the land use in the study unit (fig. 4). Other land uses are forests (4.0 percent),

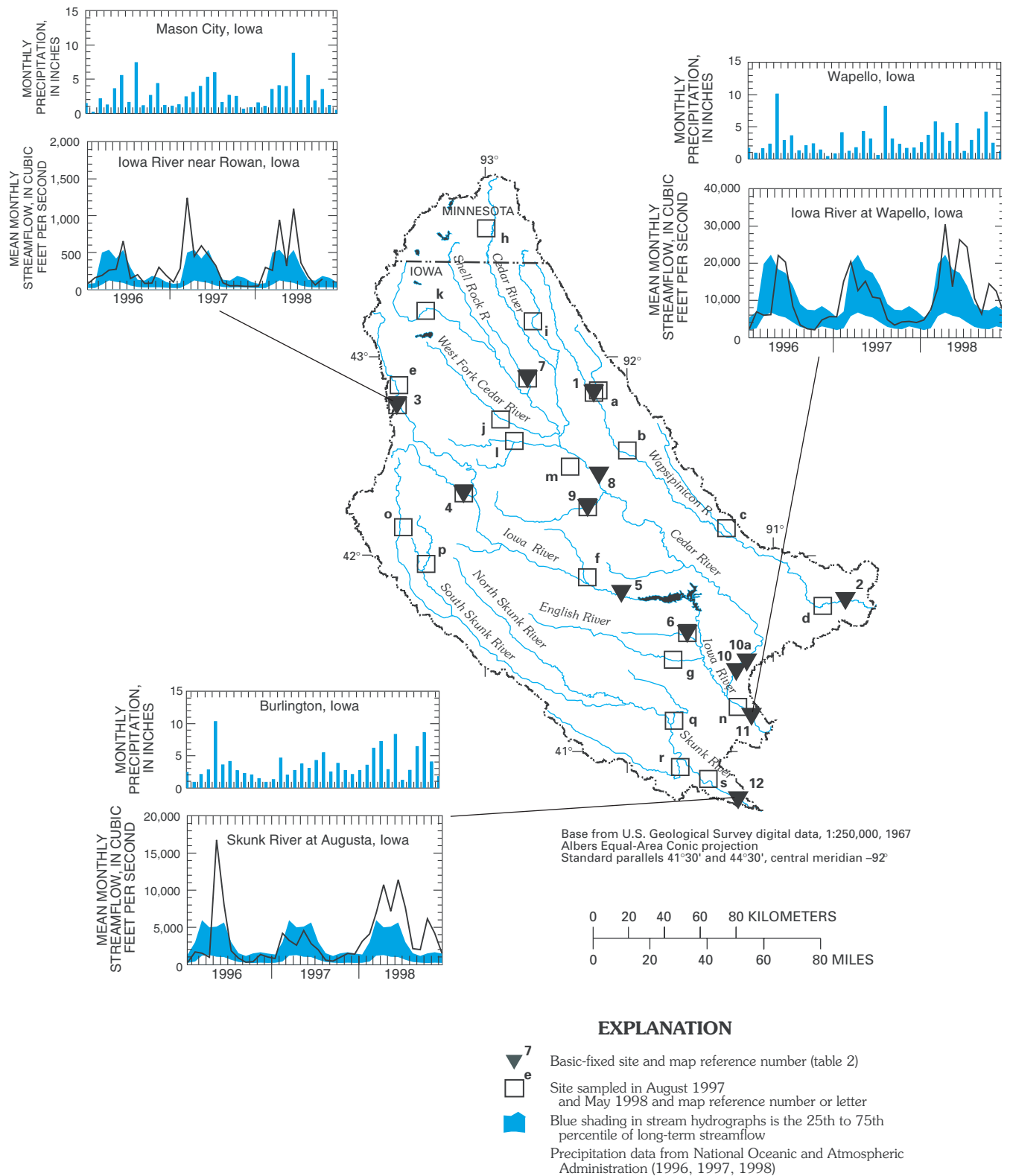


Figure 3. Precipitation and discharge at selected sites in the Eastern Iowa Basins study unit, 1996–98, and map showing site locations.

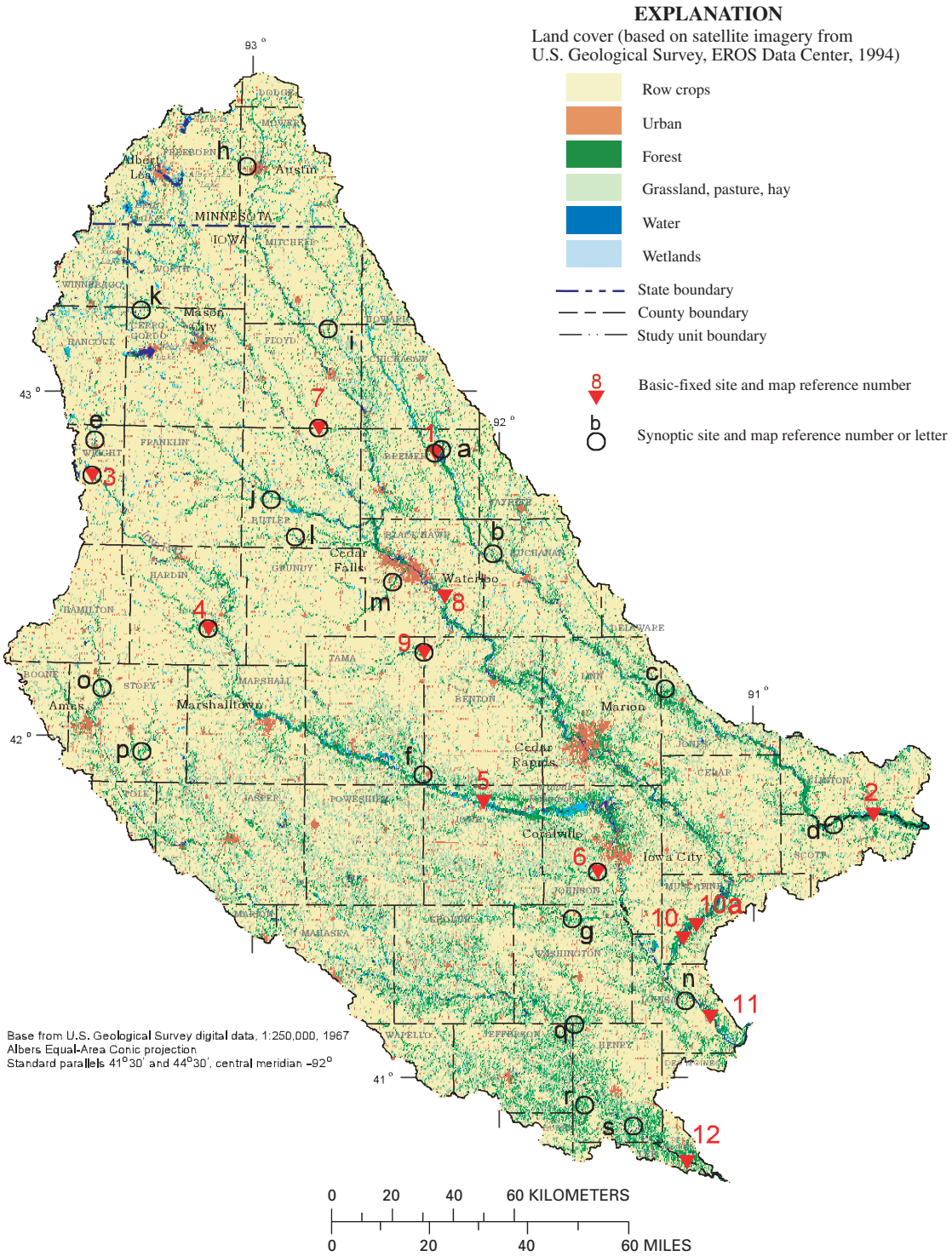


Figure 4. Land cover in the Eastern Iowa Basins study unit, 1996–98.

urban (1.8 percent), and other purposes (1.3 percent). Industry, education, and research in the largest cities (Cedar Rapids, Waterloo/Cedar Falls, and Iowa City/Coralville) contribute significantly to the economy. The principal crops are corn, soybeans, oats, hay, and pasture on unirrigated land. Iowa ranked number one in the Nation for corn for grain and soybean production in 1997 (Sands and Holden, 1998).

Pesticide Use and Properties

Pesticides (herbicides and insecticides) are commonly used to control weeds, insects, and other pests in agricultural and urban areas of the Eastern Iowa Basins (table 1). Total pesticide use and the number of different pesticides used has increased nationally since the 1960's (Larson and others, 1997, p. 3). In agricultural settings, pesticides are commonly applied by aerial spraying or ground application from tractors. During the last 20 years in Iowa, 95–99 percent of the corn and soybean crops have been treated with pesticides (Mayerfield and others, 1996 p. 18). Typically, large amounts (thousands of kilograms per year) of the common herbicides are applied annually in Iowa (fig. 5) and in the EIWA study unit.

The amounts applied of the most commonly used pesticides such as acetochlor, atrazine, cyanazine, and metolachlor are almost an order of magnitude greater than of other pesticides such as bentazone, 2,4-D, metribuzin, and trifluralin. In 1996, the pesticides atrazine, acetochlor, metolachlor, and cyanazine accounted for approximately 76 percent of the total agricultural pesticides applied in Iowa. The use of acetochlor, registered in 1994, has increased greatly, and the use of alachlor has declined (fig. 5)

Agricultural pesticides are typically applied during relatively short seasonal periods. For example, pre-emergent herbicides are applied after the seed bed has been prepared in the early spring and post-emergent herbicides are applied a few weeks after the crop germinates. The major application of herbicides in the EIWA study unit starts in late April to mid-May. Insecticides may be applied periodically throughout the growing season to control specific pests.

The physical and chemical properties of pesticides will affect their fate and transport. A detailed discussion of pesticide chemical properties is beyond the scope of this report, but some generalizations of

different pesticide groups or classes may prove helpful. One important characteristic for understanding the potential for environmental transport is the solubility of the pesticide in water. In this report, pesticides with water solubilities greater than a few parts per million are considered water soluble. Water-soluble pesticides applied to soil tend to be more mobile than nonsoluble types and can enter aquatic systems in the dissolved state. Environmental variables such as pH, hardness of water, naturally occurring organic substances (humic and fulvic acids), and biodegradation can affect the solubility of pesticides in water. In general, pesticides that are more water soluble are more likely to desorb from soils and are less likely to volatilize from water (Verschuere, 1983, p. 8).

Two classes of pesticides that are most heavily used in the EIWA study unit and throughout the Midwest are the triazine and chloroacetanilide herbicides. The most common triazines—atrazine, cyanazine, and simazine—are used primarily on corn. Less commonly used triazine pesticides include metribuzin and prometon. Metribuzin is used on soybeans and prometon is primarily used for total vegetation control in noncrop areas of farms and around outbuildings and road rights-of-way (Larson and others, 1997; Capel and others, 1999). The most commonly used chloroacetanilides (acetochlor, alachlor, and metolachlor) are used on both corn and soybeans. Both the triazines and chloroacetanilide herbicide groups have moderate to high water solubility and relatively low soil-sorption coefficients and therefore can be relatively persistent in soil (Wauchope and others, 1992). As a result, they have moderate to strong potential for transport from fields through surface runoff, primarily in the dissolved phase (Goss, 1992). In addition, most are chemically stable in water and are unlikely to volatilize from water. The triazines are somewhat more resistant to biodegradation than are the chloroacetanilides (Muir, 1991).

Pesticide degradates are formed when a parent pesticide compound breaks down or degrades. Pesticide degradates often have been detected at higher concentrations than their parent compound (Kolpin and others, 1998; Scribner and others, 1998); however, their toxicity is relatively unknown (U.S. Geological Survey, 1999, p. 77). Few, if any, Federal water-quality criteria have been set for pesticide degradates. In general, pesticide degradates are more stable than the parent compounds, though laboratory data on degra

Table 1. Common agricultural pesticides used in Iowa during 1996 and analyzed as part of the Eastern Iowa Basins study, 1996–98

[CAS number, Chemical Abstract Service registry number]

Pesticide name	Chemical class	CAS number	Use
Corn applications			
2,4-D	Chlorophenoxy acid	94-75-7	Post-emergence control of annual broadleaf weeds.
Acetochlor	Chloroacetanilide	34256-82-1	Pre-emergence, early post-emergence, or pre-plant incorporated control of most annual grasses and broadleaf weeds.
Alachlor	Chloroacetanilide	15972-60-8	Pre- and post-emergence control of most annual grasses and many broadleaf weeds.
Atrazine	Triazine	1912-24-9	Pre- and post-emergence control of most annual grasses and broadleaf weeds. Used in combination with many other herbicides.
Bentazon	Benzothiadiazole	25057-89-0	Post-emergence control of broadleaf weeds.
Bromoxynil	Nitrile	1689-84-5	Post-emergence control of broadleaf weeds.
Carbofuran	Carbamate	1563-66-2	Insecticide used on corn and soybeans. Control of soil-dwelling and foliar-feeding insects.
Chlorpyrifos	Organophosphorus; pyridine	2921-88-2	Insecticide used on cropland and in households. Control of soil insects as well as household pests (ants, cockroaches, flies).
Cyanazine	Triazine	21725-46-2	Control of annual grasses and broadleaf weeds. Used with many other herbicides.
Dicamba	Benzoic acid	1918-00-9	Control of annual grasses and broadleaf weeds. Used with many other herbicides.
EPTC	Carbamate	759-94-4	Control of annual grasses and some broadleaf weeds.
Fonofos	Organophosphorus	944-22-9	Soil insecticide used on cropland to control soil insects.
Metolachlor	Chloroacetanilide	51218-45-2	Post-emergence control of broadleaf weeds and some grasses.
Metribuzin	Triazine	21087-64-9	Pre- and post-emergence control of broadleaf weeds and grasses.
Pendimethalin	Nitro compound	40487-42-1	Control of most annual grasses and many broadleaf weeds.
Terbufos	Cyanamid	13071-79-9	Insecticide used to control soil insects.
Soybean applications			
2,4-D	Chlorophenoxy acid	94-75-7	Post-emergence control of annual broadleaf weeds.
Acifluorfen	Trifluoromethyl	62476-59-9	Pre- and post-emergence of many broadleaf weeds.
Alachlor	Chloroacetanilide	15972-60-8	Pre- and post-emergence control of most annual grasses and many broadleaf weeds.
Bentazon	Benzothiadiazole	25057-89-0	Post-emergence control of annual broadleaf weeds.
Metolachlor	Chloroacetanilide	51218-45-2	Post-emergence control of broadleaf weeds and some grasses.
Metribuzin	Triazine	21087-64-9	Pre- and post-emergence control of broadleaf weeds and grasses.
Pendimethalin	Nitro compound	40487-42-1	Control of most annual grasses and many broadleaf weeds.
Thiofensulfuron	Sulfonylurea	79277-27-3	Post-emergence control of annual broadleaf weeds.
Trifluralin	Trifluoromethyl; dinitroaniline	1582-09-8	Pre-emergence control of many annual grasses and broadleaf weeds.
Other selected pesticides			
Dieldrin	Organochlorine	60-57-1	Insecticide for locusts, termites and other public health pests.
Diuron	Urea	330-54-1	Total control of weeds on noncropland.
Prometon	Triazine	1610-18-0	Total control of weeds on noncropland. Used around outbuildings and road rights-of-way.
Simazine	Triazine	122-34-9	Herbicide for control of annual grasses and broadleaf weeds.
Tebuthiuron	Urea	34014-18-1	Total control of weeds on noncropland.

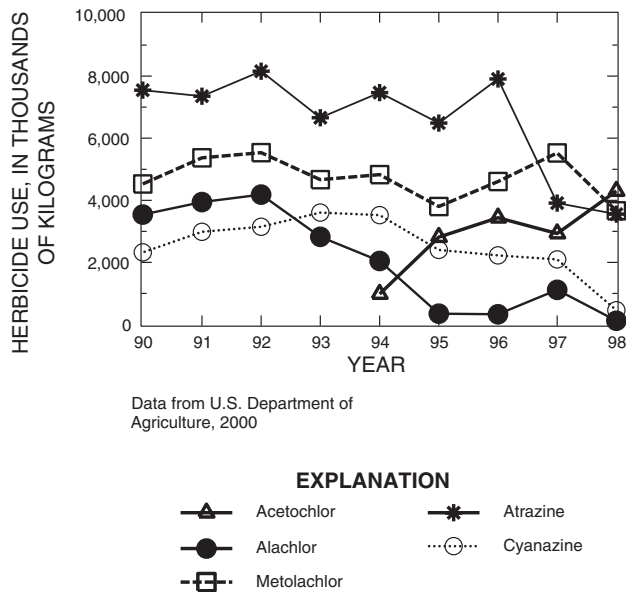


Figure 5. Use of selected herbicides in Iowa, 1990–98.

date solubilities and organic-carbon partitions are few. Some degradates can form from the degradation of more than one compound. Deisopropylatrazine can form from the degradation of either atrazine, cyanazine, or simazine (Barbash and others, 1999, p. 6). Other degradates such as deethylatrazine, hydroxyatrazine, cyanazine amide, acetochlor ethane sulfonic acid (acetochlor ESA), acetochlor oxanilic acid (acetochlor OA), alachlor ethane sulfonic acid (alachlor ESA), alachlor oxanilic acid (alachlor OA), metolachlor ethane sulfonic acid (metolachlor ESA), and metolachlor oxanilic acid (metolachlor OA) appear to be specific to their respective parent pesticide compounds (Barbash and others, 1999, p. 6).

STUDY DESIGN AND METHODS OF STUDY

The EIWA study unit design integrates water-quality information for both local and national assessment. The surface-water sampling design includes fixed-interval sampling (weekly, biweekly, and monthly), synoptic sampling (one-time sampling), and extreme-flow sampling (flood events). Surface-water sampling focuses on the physical and chemical characteristics of the streams, which include pH, dissolved oxygen, water temperature, specific conductance,

suspended sediment, dissolved solids, major ions, nutrients, organic carbon, pathogenic bacteria, dissolved pesticides, and selected pesticide degradates. Only the pesticide and pesticide degradate data will be discussed in this report. All data have been previously published (Akers and others, 1999 and 2000).

Low analytical detection limits for pesticides (often less than 0.01 µg/L) were used as part of the study design to better define temporal trends and to document concentration trends. Low detection limits allow researchers to discern correlations between pesticide exposure and human health or aquatic life health. In addition, low detection limits can increase the likelihood that pesticides not detected in analyses are truly absent from waters sampled (Phillips and others, 1998).

The target pesticides selected for analysis in surface-water samples for the NAWQA Program (Appendix 1) were selected from nearly 400 of the most commonly used pesticides in the United States (Gianessi and Anderson, 1996). The pesticides were prioritized according to three factors: national use (typically more than 3,600 kilograms of active ingredient applied annually), potential environmental significance (toxicity and leachability), and chemical properties (the ability to trap and extract the analyte from the appropriate solid-phase media) (Gilliom and others, 1995). In addition, 10 pesticide degradates (acetochlor ESA, acetochlor OA, alachlor ESA, alachlor OA, cyanazine amide, deethylatrazine, deisopropylatrazine, hydroxyatrazine, metolachlor ESA, and metolachlor OA) were added to the NAWQA target analyte list specifically for the EIWA study (Appendix 1).

The physical and water-quality characteristics of streams within the study unit are interpreted within the framework of hydrologic conditions, land use, and landforms. In particular, sampling design for pesticides and pesticide degradates collected in the EIWA study unit depended on coordinated sampling of varying intensity and scope to maximize data collection over a range of hydrologic conditions and geomorphic regions.

Sampling Site Selection

Pesticides and pesticide degradates in EIWA study unit streams and rivers were assessed by sampling selected sites at two different scales and time

periods (fig. 1). Six sites were selected on streams that were indicators of those draining different landforms and land-use patterns. Indicator sites generally represent smaller watersheds (320 to 1,080 km²) with relatively homogeneous land use and geology. An additional six sites were selected at sites on streams that integrate runoff from large watersheds containing multiple landforms and land uses. Integrator sites are large-river sites that represent large watersheds (6,050 to 32,400 km²) and are influenced by combinations of land use and point sources. Integrator sites are typically located at the mouths of the largest rivers or downstream from indicator sites. Indicator and integrator sites are referred to as basic-fixed sites in subsequent sections of this report.

Natural factors such as soils, topography, and the hydrologic system may produce differences in the concentrations and timing of pesticides in streams even though the amount of crops grown in the watershed are similar. Four indicator sites (fig. 1, table 2) were selected to investigate water-quality differences in streams draining the three major landforms—Des Moines Lobe (Iowa River near Rowan, site 3), Iowan Surface (Wolf Creek near Dysart, site 9), Southern Iowa Drift Plain (Old Mans Creek near Iowa City, site 6), and Iowan Karst subarea (Flood Creek near Powersville, site 7).

Land use was the primary factor in selection of two additional indicator sites. Parts of the Wapsipinicon River bottomland have remained relatively unaltered by human activities, and thus the stream is unchannelized with larger amounts of wetlands and undisturbed flood plain than other streams in the study unit. Although the uplands are used for row-crop agriculture, the Wapsipinicon River near Tripoli (site 1) was selected as a defined “reference” site to investigate the effects of the natural flood plain on stream-water quality. Since the late 1980’s and early 1990’s, animal feeding operations have moved from a large number of smaller facilities to a smaller number of large-scale confinement facilities. These confinement facilities generate a substantial amount of animal waste that, if not properly applied, may be washed into streams or infiltrate into the ground water. An indicator site, South Fork Iowa River near New Providence (site 4) was selected to investigate the effect of the large-scale hog-confinement facilities on stream water quality.

Sites near the mouth of the Wapsipinicon, Iowa, and Skunk Rivers (fig. 1, table 2) were selected to

assess broadscale seasonal and spatial changes in pesticide concentrations in the larger rivers within the study unit. Data collection at these sites also was intended to provide information to estimate the amount of pesticides and pesticide degradates transported to the Mississippi River. The site on the Cedar River near Conesville (site 10) was selected to document the quality of the largest tributary to the Iowa River. Water-quality sampling was moved about 13 km upstream to a site (site 10a) near Nichols in October 1996 because of bridge construction. Water-quality data collected from the Cedar River near Nichols was considered to be representative of the Cedar River near Conesville since there are no major tributaries or urban areas on the Cedar River between the sites. Data collected at both sites will be discussed as originating from the Cedar River near Conesville in the remainder of this report.

The Iowa River at Marengo (site 5, fig. 1, table 2) was selected as a site representative of the Iowa River upstream from the Coralville Reservoir. Previous studies have shown that certain pesticide concentrations are altered as water flows through the Coralville Reservoir (Schnoor, 1981); thus, a site upstream from the reservoir was necessary to assess the quality of Iowa River unaffected by reservoirs. In 1996, the Cedar River at Gilbertville (site 8) was sampled to evaluate the effects of an urban area (Waterloo, Iowa) on water quality.

Streams on 25 medium-sized (from about 310 km² to about 1,500 km²) watersheds were sampled during base-flow conditions in August 1997 and May 1998 as part of a regional synoptic study to characterize the chemical, biological, and habitat conditions in Midwest streams (Sorenson and others, 1999). Sites were selected to represent small to medium agricultural watersheds and to include moderately well drained to poorly drained soils (Sorenson and others, 1999). Agricultural land use among all sites in the synoptic study exceeded 90 percent. Six of the synoptic sites were existing EIWA indicator sites.

Sampling Methods

Water-quality sample collection and streamflow measurements were made monthly at the basic-fixed sites to assess the seasonal and spatial character of selected constituents. In addition, three basic-fixed sites (fig. 1, table 2)—Iowa River near Rowan (site 3),

Table 2. Description of surface-water-quality sampling sites in the Eastern Iowa Basins study unit

[bfs, basic-fixed site sampled monthly; ind, indicator site representing small to medium sized drainage basins of uniform land use; int, integrator site representing large drainage basins of mixed land use; intens, intensive site sampled weekly in spring and early summer 1997 and biweekly at end of summer 1997; syn, synoptic site; <, less than; -- data not available]

Map reference number or letter (fig. 1)	Site number	Site name	Drainage area (square kilometers)	Site type	Land use in contributing drainage area (percent) ¹				
					Agriculture	Urban	Forested	Wetland	Other (barren/water)
1	05420680	Wapsipinicon River near Tripoli, IA	900	bfs, ind, syn	88.5	1.8	5.1	4.2	0.3
2	05422000	Wapsipinicon River near DeWitt, IA	6,050	bfs, int	87.4	2.1	7.2	2.7	.6
3	05449500	Iowa River near Rowan, IA	1,080	bfs, intens, ind, syn	94.6	1.8	1.6	1.5	.6
4	05451210	South Fork Iowa River near New Providence, IA	580	bfs, ind, syn	95.1	1.5	2.6	0.7	< .1
5	05453100	Iowa River at Marengo, IA	7,240	bfs, int	91.0	2.5	3.9	2.1	.6
6	05455100	Old Mans Creek near Iowa City, IA	520	bfs, ind, syn	91.9	2.6	4.4	1.0	.1
7	05461390	Flood Creek near Powersville, IA	320	bfs, ind, syn	95.3	1.1	2.8	.8	< .1
8	05464020	Cedar River at Gilbertville, IA ²	13,600	bfs, int	90.7	3.0	3.5	1.9	.9
9	05464220	Wolf Creek near Dysart, IA	770	bfs, intens, ind, syn	95.6	1.8	1.9	.6	.1
10a	05464935	Cedar River near Nichols, IA ³	19,570	bfs, int	--	--	--	--	--
10	05465000	Cedar River near Conesville, IA	20,200	bfs, int	89.5	3.3	4.4	1.9	.9
11	05465500	Iowa River at Wapello, IA	32,400	bfs, intens, int	89.0	3.1	4.9	2.1	.9
12	05474000	Skunk River at Augusta, IA	11,200	bfs, int	87.1	2.9	7.7	1.8	.5
a	05420720	East Fork Wapsipinicon River near Tripoli, IA	370	syn	90.4	1.3	5.0	3.0	.2
b	05420900	Little Wapsipinicon River at Littleton, IA	380	syn	89.0	2.3	7.4	1.1	.2
c	05421700	Buffalo Creek near Stone City, IA	600	syn	90.1	2.2	6.6	1.6	.2
d	05421870	Mud Creek near Donahue, IA	310	syn	94.7	2.2	2.8	.2	< .1
e	05449200	East Branch Iowa River at Belmond, IA	500	syn	95.4	1.8	1.5	.9	0.3
f	05452020	Salt Creek at Belle Plaine, IA	560	syn	93.0	2.4	3.6	1.0	0.1
g	05455500	English River near Kalona, IA	1,500	syn	91.2	2.5	4.7	1.3	0.2
h	05456510	Turtle Creek at Austin, MN	400	syn	90.7	1.9	3.4	1.7	2.2
i	05457950	Little Cedar River near Floyd, IA	610	syn	93.4	1.3	3.4	1.5	0.2
j	05458870	Maynes Creek near Kelsey, IA	350	syn	95.0	1.1	3.0	0.7	0.1
k	05459300	Winnebago River near Fertile, IA	760	syn	91.4	2.0	2.6	3.3	0.7
l	05462770	Beaver Creek near Parkersburg, IA	370	syn	95.5	1.4	2.3	0.7	0.1
m	05463510	Black Hawk Creek at Waterloo, IA	850	syn	95.4	2.0	1.4	1.0	0.1
n	05465310	Long Creek near Columbus Junction, IA	400	syn	90.8	2.3	6.3	0.6	0.1
o	05469980	South Skunk River near Story City, IA	570	syn	94.0	3.1	1.9	0.6	0.4
p	05471120	East Branch Indian Creek near Iowa Center, IA	330	syn	93.6	2.2	3.3	0.7	0.2
q	05473060	Crooked Creek at Coppock, IA	740	syn	90.5	2.4	6.2	0.7	0.1
r	05473400	Cedar Creek near Oakland Mills, IA	1,400	syn	85.4	2.2	10.0	2.2	0.2
s	05473550	Big Creek near Lowell, IA	420	syn	87.2	3.3	8.2	1.2	0.1

¹Land-use data from Hitt, 1994.

²Cedar River at Gilbertville was discontinued as a basic-fixed site in March 1997.

³Sampling was moved upstream to site near Nichols (site 10a) in October 1996 because of bridge construction at the Conesville site (site 10).

Wolf Creek near Dysart (site 9), and Iowa River at Wapello (site 11)—were sampled intensively (weekly and biweekly) during 1997 to define short-term variability.

The 12 basic-fixed sites were sampled monthly starting in March 1996 through March 1997 for pesticides and pesticide degradates. Sampling at the Cedar River at Gilbertville (site 8) was discontinued in April 1997. During April 1997 through March 1997 the collection of water samples for pesticide and pesticide degradates continued at only three basic-fixed sites. The three sites were sampled weekly starting in April through June 1997, biweekly from July through November 1997, and monthly from December 1997 through March 1998. In April 1998, monthly sampling for pesticides and pesticide degradates resumed at all the basic-fixed sites (except Gilbertville) and continued through September 1998.

Samples were collected over the complete range of flow conditions including peak river stage after significant rainfall events. A total of 353 samples were collected for pesticide analysis at the basic-fixed sites, and 77 samples were collected for quality assurance/quality control (blanks, spikes, and replicates).

Representative samples were obtained by collecting depth-integrated subsamples at equally spaced vertical sections across the stream (Ward and Harr, 1990) to account for any instream variability. A minimum of 10 equally spaced verticals and depth-integrated water samples were collected using a cable-mounted or hand-held sampler (Shelton, 1994). Subsamples from five equally spaced verticals were collected from streams that were less than about 4 m wide. Samples were collected in Teflon bottles using Teflon nozzles. During ice conditions, samples were generally collected from a minimum of three equal-width vertical sections.

Water temperature, specific conductance, pH, and dissolved oxygen were measured using a multi-parameter meter. Measurements were made at equal-width increments across the stream section, and the median value was recorded as the value for the field parameter. Streamflow was obtained from instantaneous streamflow measurements or from streamflow records obtained from continuous gaging stations located at each of the sites. In addition to pesticides, water samples were collected for analysis of major ions, dissolved and suspended organic carbon, nutrients, and suspended sediment (Akers and others, 1999 and 2000).

All equipment used to collect and process pesticide samples was precleaned with a 0.1-percent non-phosphate detergent, triple rinsed with tap water, triple rinsed with deionized water, and rinsed with methanol that was certified by the manufacturer to be free of pesticides. Once cleaned, equipment was air dried, wrapped in aluminum foil, and stored in a dust-free environment (Shelton, 1994) to ensure clean equipment for the next sample.

Water samples for pesticide and pesticide degradates were filtered through a 142-millimeter-diameter, 0.7-micrometer (μm) pore size, borosilicate glass-fiber filter placed in a stainless steel filter unit (Sandstrom, 1995). The filtered water was collected in amber-colored bottles and chilled for later analysis of pesticides and pesticide degradates. Both the glass-fiber filters and amber-colored bottles had been precleaned by baking at 450°C in a muffle furnace for at least 2 hours. Filtered water for pesticide analysis using gas chromatograph/mass spectrometer (GC/MS) techniques were extracted in the field laboratory at the sampling site by pumping filtered water through solid-phase extraction (SPE) cartridges. Detailed descriptions of the SPE method are given in Shelton (1994) and also by Sandstrom and others (1992). The SPE cartridges were stored in amber vials, chilled, and sent by overnight air express to the USGS National Quality Laboratory (NWQL) for analysis. Filtered water samples for pesticide degradate analysis also were kept on ice and sent to the USGS Organic Geochemistry Research Laboratory (OGRL) in Lawrence, Kansas.

Analytical Methods

Water samples were analyzed by the NWQL for two separate suites of pesticide compounds. Forty-eight pesticides and pesticide degradates (Appendix 1) were analyzed by capillary-column (GC/MS) with selected-ion monitoring (Zaugg and others, 1995). Additionally, high performance liquid chromatography (HPLC) techniques are used to analyze 44 pesticide compounds (Appendix 1) that are not readily amenable to gas chromatography or other high temperature analytical techniques (Werner and others, 1996). By using these laboratory methods it is sometimes possible to detect pesticide concentrations that are below the method detection limit (MDL) (Pritt, 1994). The MDL is defined as the minimum concentration of

a substance that can be identified, measured, and reported with 99-percent confidence that the compound concentration is greater than zero (Wershaw and others, 1987). At times when concentrations are below the MDL, the compound has been positively identified, but the numerical value of the concentration has a larger variability than those values that are above the method detection limit. Therefore, a concentration reported below the MDL is identified with an “E” (estimated) code beside the value.

The OGRL analyzed 10 pesticide degradates in water samples following solid-phase extraction (SPE) on octadecyl (C-18 cartridges) (Thurman and others, 1990; Meyer and others, 1993). Analyses for six chloroacetanilide herbicide degradates—acetochlor ESA (ethane sulfonic acid), acetochlor OA (oxanilic acid), alachlor ESA, alachlor OA, metolachlor ESA, and metolachlor OA—and one atrazine degradate, hydroxyatrazine, were analyzed by HPLC following solid-phase extraction in the field (Meyer and others, 1993; Ferrer and others, 1997). The other three pesticide degradates—deethylatrazine, deisopropylatrazine, and cyanazine-amide—are determined by GC/MS operated in selected ion-monitoring (SIM) mode following solid phase extraction (Zimmerman and Thurman, 1999). The method detection limit for deethylatrazine, deisopropylatrazine, and cyanazine amide was 0.05 µg/L and for all the other degradate compounds was 0.2 µg/L.

Quality Assurance/Quality Control

To ensure that data are reliable and accurate and to properly interpret water-quality data, information is needed to estimate the bias and variability that can result from sample collection, sample processing, sample shipment, and laboratory analysis. Bias is systematic error that can “skew” results in either a positive or negative direction. The most common source of positive bias in water-quality studies is contamination of samples from airborne gases and particulates or inadequately cleaned sampling equipment. Variability is the degree of random error of independent measurements of the sample quantity. Variability may be the result of errors in laboratory analytical procedures or in collection of samples in the field. Quality assurance/quality control (QA/QC) procedures are required to ensure that the data collected meet standards of reliability and accuracy.

The QA/QC design for the NAWQA surface-water sampling is described in detail by Mueller and others (1997). The EIWA study unit followed the design guidelines of Mueller and others (1997). About 15 to 20 percent of the total samples collected for the EIWA study unit were analyzed for quality control and included equipment blanks, field blanks, field spikes, and replicates. Generally, blanks and spikes are used to estimate sample bias while replicates are used to estimate sample variability.

A blank is a water sample that is intended to be free of the analytes of interest. Equipment blank samples of deionized water guaranteed by the manufacturer to be free of organic compounds and deionized water guaranteed by the manufacturer to be free of inorganic compounds were passed through all sampling equipment at the beginning of the field season. Equipment blank samples are collected in a “clean” environment such as the laboratory to examine the cleanliness of the equipment prior to sampling. A field blank is a specific type of blank sample collected in the field and used to demonstrate that: (1) equipment has been adequately cleaned to remove contamination introduced by samples obtained at the previous site; (2) sample collection and processing have not resulted in contamination; and (3) sample handling, transport, and laboratory analysis have not introduced contamination (Mueller and others, 1997). Field blank samples of the same deionized organic-free water that was used with equipment blank samples were collected by passing the deionized, organic-free water through all pumps, filter plates, and filters to verify cleanliness of sampling equipment and technique. Field-blank sample concentrations for pesticide constituents were typically equivalent to the MDL. In other words, the blanks were “clean” and did not indicate any pesticide contamination from the equipment or sample processing methods. There was no cross-contamination of samples from sampling equipment between sample collection.

A spike is an environmental sample that is injected with a known mass of a specific analyte. A field spike is a specific type of spiked sample that is injected in the field prior to shipping. Field spikes are used to test for bias resulting from matrix interference or analyte degradation. Matrix interference is the effect that the matrix of the water sample itself has on the measurement of individual analytes within that sample. Bias is estimated from field spikes by calculating the percentage of the added analyte that is

measured (recovered) in the sample. Spike recovery calculations are described by Mueller and others (1997, p. 5). The recovery of the spike can either be greater or less than 100 percent, so the bias can be either positive or negative. Typically, matrix interference and analyte degradation generally result in negative bias for spike recovery (Mueller and others, 1997).

Table 3 summarizes the percent recovery data for commonly detected pesticides from 19 water samples that were spiked in the field. The mean spike recoveries ranged from 83 to 108 percent and the median spike recoveries ranged from 83 to 106 percent.

In addition, a “high spike” recovery experiment was performed to check the recovery of selected pesticide compounds at higher spike concentrations (3 and 6 µg/L) in sample water. Three water samples collected at Old Mans Creek near Iowa City (site 6) were spiked at low (0.1 µg/L), medium (3 µg/L), and high (6 µg/L) concentrations. The spike recoveries at the higher concentrations (3 and 6 µg/L) were not significantly different than those done at the lower (0.1 µg/L) concentrations.

Replicates are two or more samples collected or processed so that the samples are considered to be essentially identical in composition. Split replicates are prepared by dividing a single volume of sampled water into multiple samples. All replicates collected for the EIWA study unit were split replicates. Each replicate sample is an aliquot of the native water sample that is processed and prepared in the same way as the environmental sample. A replicate sample set consists of two samples—a regular environmental

sample and the replicate environmental sample. For the purposes of this report, the terms “regular environmental sample” and “replicate environmental sample” are used to identify the particular samples in a replicate pair.

One objective of the replicate samples was to estimate the precision of concentration values from sample processing and analysis. Analyses of organic constituents are generally more variable than analyses of inorganic constituents. Replicate samples were compared by using relative percent differences. Relative percent difference (RPD) between replicate samples was calculated by equation:

$$RPD = \frac{|S1 - S2|}{(S1 + S2)/2} \times 100 \quad (1)$$

where:

S1 is equal to the concentration in the regular environmental sample, in micrograms per liter; and

S2 is equal to the concentration in the replicate sample, in micrograms per liter.

Typically, if the relative percent difference is large it can indicate greater variability in those samples. In general, the replicate pesticide degradate samples had more variability than the replicate parent pesticide compound samples. The median RPD for the degradates ranged from 0 to 13.6 percent (table 4), and the median RPD for the parent pesticides ranged from 0.1 to 5.3 percent.

Surrogates are added to all environmental and quality-control samples for pesticide analysis before sample preparation. A surrogate is similar to the physical and chemical properties of the analytes of interest but is not normally found in environmental samples. Typically, the number of surrogates varies from one to four compounds. Surrogates provide quality control by monitoring matrix effects and gross processing errors (Wershaw and others, 1987). Surrogate recoveries are expressed in percent and typically range from 80 to 120 percent.

Data Analysis

Summary statistics and graphical analysis were used to examine the seasonal and spatial distribution of pesticide and pesticide degradate concentration data. Statistical analysis and ancillary data sets were important parts of the data analysis. Tables and

Table 3. Summary of percent recovery data for commonly detected pesticides spiked in the field for the Eastern Iowa Basins study unit, 1996–98

Constituent	Spike recovery, in percent			
	Minimum	Maximum	Mean	Median
Acetochlor	78	142	105	101
Alachlor	84	139	108	106
Atrazine	83	132	107	105
Cyanazine	35	162	90	91
Metolachlor	19	163	104	102
Metribuzin	57	110	83	83
Prometon	23	118	96	99
Simazine	84	124	98	98
Trifluralin	67	116	88	84

Table 4. Summary of replicate sample data for commonly detected parent pesticide and degradate pesticide compounds

[ESA, ethane sulfonic acid; OA, oxanilic acid]

Constituent	Number of replicate samples	Median relative percent difference	Number of replicate samples with greater than 10 percent relative percent difference
Parent pesticide compounds			
Acetochlor	18	1.6	2
Alachlor	18	0.1	3
Atrazine	18	1.8	2
Cyanazine	18	5.1	6
Metolachlor	18	1.5	1
Prometon	18	5.3	5
Degradate pesticide compounds			
Acetochlor ESA	20	12	11
Acetochlor OA	19	0	2
Alachlor ESA	20	7	8
Alachlor OA	19	0	1
Hydroxyatrazine	19	0	5
Deethylatrazine	17	0	4
Deisopropylatrazine	17	5.7	9
Cyanazine amide	16	0	4
Metolachlor ESA	20	2.5	3
Metolachlor OA	19	13.6	9

specific graphs of selected, most commonly detected pesticides were used to support relevant descriptions and discussion. A complete listing of all the pesticide concentration data collected for the EIWA study unit for 1996–98 can be found in Akers and others (1999 and 2000).

Statistical Analysis of Pesticide and Pesticide Degradates

Pesticide and pesticide-degradate data were graphically represented using boxplots to show the median and variability of the data. In this plot, a box is drawn from the 25th to the 75th quartile (interquartile range), and the median is shown as a horizontal line in the box. Lines are drawn from the ends of the box to the most extreme data values within or equal to 1.5 times the interquartile range outside the quartile.

Outlier values can be shown above or below the lines on the boxplot with an asterisk or circle. Boxplots are useful for visually displaying variability when comparing data between sites.

The Statistical Analysis System (SAS Institute Inc., 1989) was used to calculate summary statistics such as mean, median, minimum, and maximum concentrations for chemical data. The Wilcoxon rank-sum and Kruskal-Wallis nonparametric statistical tests (Helsel and Hirsch, 1992) were used to evaluate the statistical significance of concentration differences between groups of data. The probability (p) values generated by these statistical tests are used to quantify that concentration differences between groups of data are not the result of chance occurrence. A p-value of 0.05 indicates a 95-percent confidence that the observed differences are not the result of chance occurrence. In this report, differences between groups with p-values of 0.05 or less were considered significant.

Ancillary Data

Several ancillary data sets were developed in an effort to better understand the relation of pesticide concentrations in streams and rivers to natural and anthropogenic factors. Data sets with information on ground water, streamflow, surface-water runoff, basin characteristics, soil characteristics, and agricultural statistics (amounts of pesticides applied, planting data, and harvest data) were compiled and summarized in an effort to better understand the fate and transport of pesticide and pesticide degradates.

Ground-water discharge and surface-water runoff that constituted the streamflow at the basic-fixed sampling sites were estimated by separating streamflow hydrographs into their base-flow and surface-runoff components using the Base Flow Indicator (BFI) program (Wahl and Wahl, 1995). Computer separation of the streamflow hydrograph mimics the traditional manual methods (Rorabaugh, 1963; Linsley and others, 1982) and at the same time removes many of the inconsistencies of the manual methods.

PESTICIDES AND PESTICIDE DEGRADATES IN STREAMS

The pesticide and pesticide degradate data were evaluated in terms of occurrence (what pesticide compounds were found and how many), seasonal variability (when the pesticides compounds were found) and spatial variability (where the pesticides were found). Water-quality criteria and guidelines are used to evaluate the potential effects of the pesticides on humans (Appendix 1). However, potential risks to humans and aquatic life only can be partially addressed by comparison to established criteria and guidelines. Often the range of potential effects of pesticides is based on controlled experiments for a single contaminant over a small range of concentrations. Historically, data on the toxicity of mixtures of pesticides and of many of the pesticide degradates are unknown (U.S. Geological Survey, 1999, p. 76–77). Evaluating any potential effects of pesticides and what effects may occur from varying types and duration of exposure is beyond the scope of this report. Documentation on the occurrence, composition, and patterns of pesticides and pesticide degradates is important in developing a better understanding of the fate and transport of these compounds and their possible effects on the environment.

Occurrence and Distribution

The most commonly applied pesticides in Iowa—acetochlor, atrazine, cyanazine, and metolachlor—are among those most often detected in streams in the EIWA study unit (fig. 6). Less frequently detected pesticides were generally those with lower use. Atrazine and metolachlor, the two most commonly used herbicides in Iowa for row-crop agriculture during 1996–98, were detected in all stream samples (fig. 6). Acetochlor, alachlor, and cyanazine were detected in more than 70 percent of the samples. Less frequently detected pesticides were 2,4-D, EPTC, trifluralin, metribuzin, dicamba, and carbofuran, which were applied in Iowa at a rate of only 0.6 to 30 percent of the rate of application for atrazine (Sands and Holden, 1998). Alachlor was heavily applied in the 1980’s, but its use has rapidly decreased in the last 5 years as it is being replaced by acetochlor (fig. 5). Alachlor was commonly detected at low concentrations in rivers and streams in the EIWA study unit (fig. 6).

Forty-seven pesticides (table 5) that were analyzed for were not detected in streams in eastern Iowa and southern Minnesota. These compounds generally were not used or were applied in small amounts in the study unit.

Acetochlor, alachlor, atrazine, cyanazine, and metolachlor were generally detected at low concentrations, with median concentrations ranging from 0.01 to 0.50 µg/L (Appendix 2). However, the maximum concentrations of these compounds were as large as 48.1 µg/L, but alachlor had a maximum concentration of only 0.559 µg/L. Most atrazine concentrations (76 percent) exceeded 0.1 µg/L with almost 60 percent

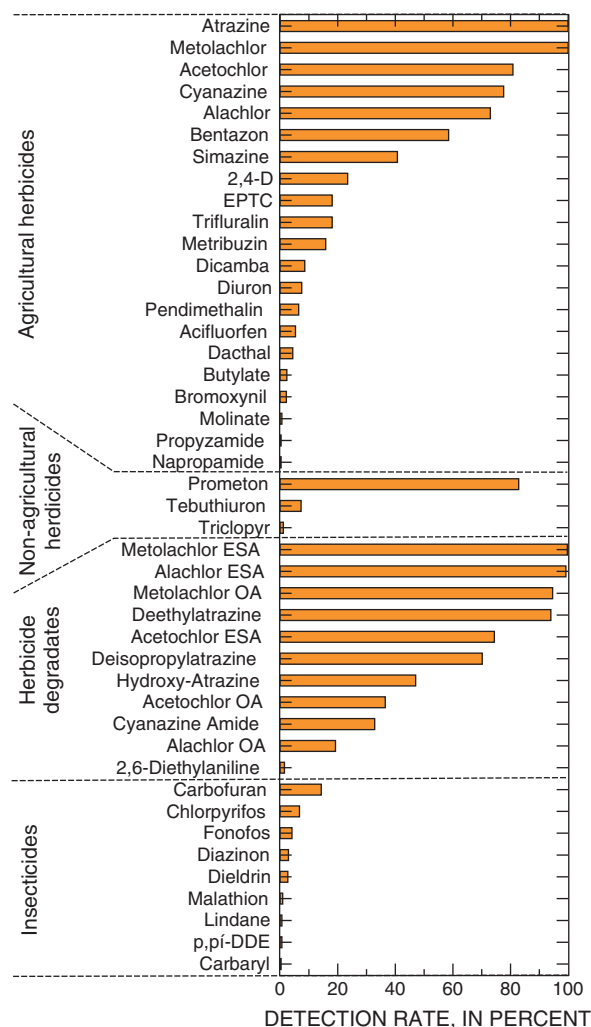


Figure 6. Occurrence of pesticide compounds at basic sampling sites in the Eastern Iowa Basins study unit, 1996–98.

Table 5. Pesticide compounds not detected in surface-water samples in the Eastern Iowa Basins study unit, 1996–98

[µg/L; micrograms per liter]

Constituent	Method detection limit (µg/L)	Constituent	Method detection limit (µg/L)
2-(2,4,5-trichlorophenoxy) propionic acid	0.06	Linuron	0.002
2,4,5-T	.040	Methomyl	.017
2,4-DB	.10	MCPA	.17
4,6-Dinitro-2-methylphenol	.42	MCPB	.13
Aldicarb	.21	Methiocarb	.026
Aldicarb sulfone	.10	Neburon	.07
Aldicarb sulfoxide	.021	Norflurazon	.042
Azinphos, methyl-	.001	Oryzalin	.31
Benfluralin	.002	Oxamyl	.018
Bromacil	.06	Parathion	.004
Carbofuran, 3-hydroxy-	.29	Parathion, methyl-	.006
Chloramben (Amiben)	.14	Pebulate	.004
Chlorothalonil	.48	Permethrin, <i>cis</i> -	.004
Clopyralid	.23	Phorate	.002
Dacthal, mono-acid	.039	Picloram	.05
Dichlobenil	.07	Propham	.035
Dichlorprop (2,4-DP)	.032	Propachlor	.007
Dinoseb (DNBP)	.06	Propanil	.004
Disulfoton	.017	Propargite	.013
Ethylfluralin	.004	Terbacil	.007
Ethoprophos	.003	Terbufos	.013
Fenuron	.07	Thiobencarb	.002
Fluometuron	.06	Triallate	.001
HCH, <i>alpha</i> -	.002		

of the samples in the 0.1 to 1.0 µg/L range (fig. 7). About 10 percent of the samples exceeded the MCL for atrazine of 3.0 µg/L (U.S. Environmental Protection Agency, 1995). Almost half of the samples had metolachlor concentrations in the range from 0.1 to 1.0 µg/L (fig. 7).

Acetochlor was frequently detected, but in most samples (75 percent) at concentrations less than 0.1 µg/L. Acetochlor concentrations did not exceed the USEPA 2.0-µg/L annual mean concentration registration requirement (U.S. Environmental Protection Agency, 1994a) at any site but did exceed this concentration in about 3 percent of the individual samples. The maximum concentration (10.6 µg/L) measured during the study exceeded the concentration that would trigger requirements for biweekly sampling for water-supply systems (U.S. Environmental Protection Agency, 1994a).

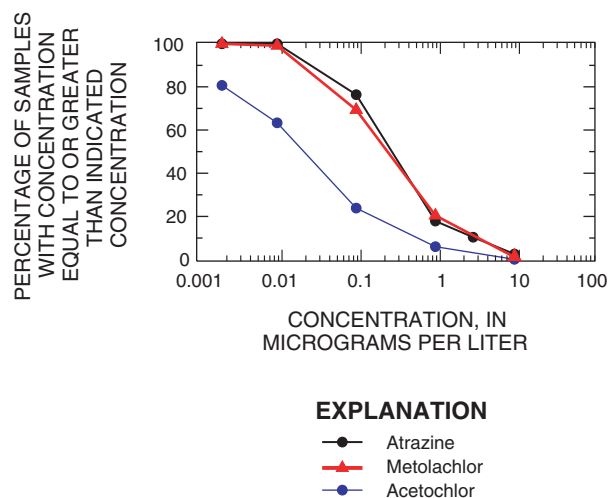


Figure 7. Frequency distribution of selected herbicide concentrations at basic-fixed sampling sites in the Eastern Iowa Basins study unit, 1996–98.

Many pesticides are used in both agricultural and urban settings, but three herbicides used almost exclusively in non-row-crop agriculture and urban settings (prometon, tebuthiuron, and triclopyr) also were present in streams in the EIWA study unit from 1996 through 1998 (fig. 6). Prometon was one of the 10 most frequently detected pesticides in the study unit and was present at very low concentrations (less than 0.1 µg/L) in more than 80 percent of the samples even though it is not used as a herbicide for crop areas. Median concentrations of prometon were low at all sites—typically less than 0.15 µg/L. The occurrence of prometon at all sites in small but fairly consistent concentrations is consistent with its application in the study unit and relatively long environmental life. Unlike most agricultural herbicides, prometon typically has a continuous, albeit low-level, presence in surface waters because there are no efficient loss mechanisms for removing prometon from the hydrologic system (Capel and others, 1999). Tebuthiuron, used on road rights-of-way and industrial sites, was detected in 7 percent of the samples. Triclopyr, used on road rights-of-way, industrial sites, and turf grass, was detected in 1 percent of the samples.

Several insecticides that have been identified as posing a high risk to aquatic invertebrates were detected in streams (fig. 6). Carbofuran was the most frequently detected insecticide (16 percent of all samples from streams). Although detected in only 16 percent of all samples, carbofuran was detected in 68 percent of the samples collected in June. When present, carbofuran concentrations generally were less than 0.80 µg/L. Chlorpyrifos was detected in about 7 percent of the samples. As with most other insecticides, chlorpyrifos was detected most frequently in June (about 30 percent of the samples). The maximum concentration was 0.067 µg/L. Malathion was detected in three samples in spring and early summer at concentrations that ranged from 0.023 to 0.078 µg/L. Lower use relative to herbicides, short persistence, and application during periods of reduced runoff probably account for the overall low detection rate and low concentrations of insecticides in rivers and streams.

The pesticide-degradate compounds were some of the most frequently detected pesticide compounds in streams (fig. 6) and on average constituted the majority of the pesticide mass in water samples. Metolachlor OA, alachlor ESA, metolachlor ESA, deethylatrazine, and acetochlor ESA were detected in more than 75 percent of the samples. The frequent occurrence of the degradates is even more striking

when comparing the parent pesticides and their degradates at a higher but common method detection level of 0.2 µg/L (the MDL for the degradates) (fig. 8). The degradates were detected much more frequently than their parent compounds with the exception of two degradates of atrazine—deethylatrazine and deisopropylatrazine (fig. 8). The degradates metolachlor ESA, alachlor ESA, metolachlor OA, and acetochlor ESA were detected in 75 to 100 percent of the samples compared to 4 to 55 percent for their respective parent compounds (fig. 8). In particular, the difference between detection frequencies of alachlor and alachlor ESA (using the 0.2-µg/L MDL) is large. Alachlor ESA is detected in almost all samples, and alachlor is detected in only about 4 percent of the samples (fig. 8). Even though alachlor usage has strikingly declined in the last 10 years (fig. 5), its degradate, alachlor ESA, is still one of the most frequently detected compounds in streams in the EIWA study unit.

In addition to being detected more frequently, concentrations of degradates were larger than their parent compounds. Median concentrations for the pesticide-degradate compounds ranged from 0.07 to 3.7 µg/L (Appendix 2), which were larger than their parent pesticide compounds (median concentrations 0.01 to 0.22 µg/L). However, the pesticide degradates typically had lower maximum concentrations when compared to the parent compounds. Maximum

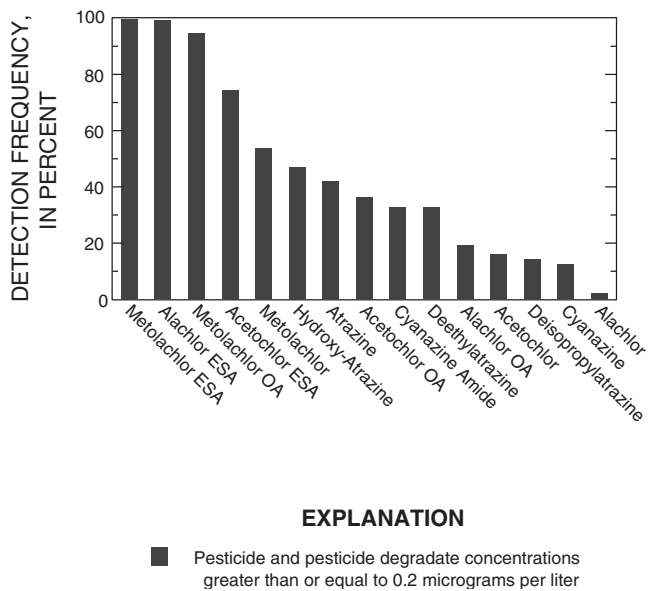


Figure 8. Occurrence of pesticide and pesticide degradates basic-fixed sampling sites using a common reporting limit.

concentrations for the degradates ranged from 0.7 to 12.4 µg/L (Appendix 2).

On average, approximately 83 percent of the total pesticide mass (parent compounds and degradates) in each sample can be accounted for by 10 common degradates of acetochlor, alachlor, atrazine, cyanazine, and metolachlor. Concentrations of acetochlor ESA, alachlor ESA, and metolachlor ESA commonly were more than 10 times larger than their parent compounds.

The use of a wide variety of pesticides in the EIWA study unit is reflected by the presence of multiple pesticide compounds in streams (fig. 9). Two or more compounds were detected in every sample, and five or more compounds were detected in 50 percent of the stream samples (fig. 9). As many as 16 pesticide compounds were detected in a single stream sample. Two pesticide compounds, atrazine and metolachlor, were detected in 100 percent of the samples analyzed (fig. 6). Mixtures of several pesticide degradates also were commonly found. At least one pesticide degradate, metolachlor ESA, was present in each water sample analyzed (fig. 9). Approximately 68 percent of all the samples collected contain four or more pesticide degradates and approximately 17 percent of all samples contain seven or more pesticide degradates (fig. 9).

Seasonal Variability

Pesticide concentrations vary throughout theyear in samples collected at the basic-fixed sites

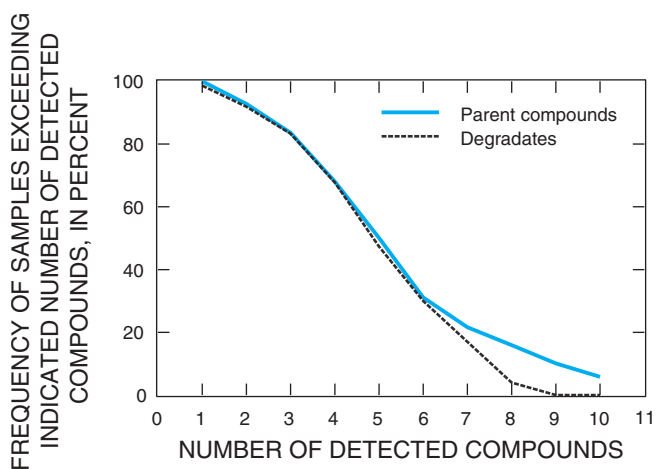
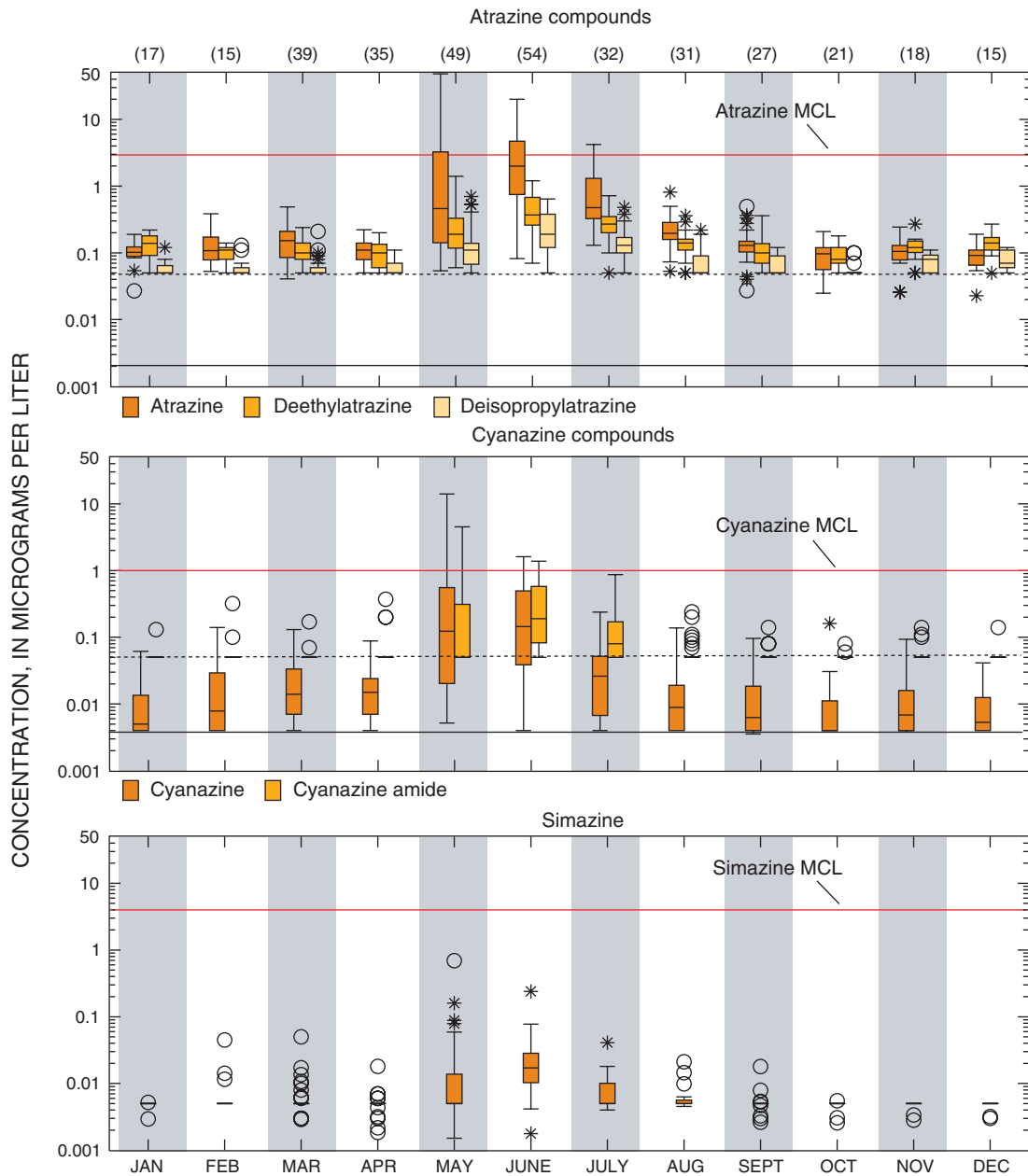


Figure 9. Detection of multiple compounds in samples from streams at basic-fixed sampling sites in Eastern Iowa Basins study unit, 1996–98.

on Eastern Iowa Basins streams with the greatest concentrations generally occurring during rainfall-runoff periods soon after application in late spring and early summer. Concentrations of almost all pesticides peak in May and June following application and then decrease during the growing season (figs. 10 and 11). The exceptions were prometon, dicamba, and 2,4-D. In addition, there is a secondary peak in concentration of triazine and chloroacetanilide herbicides that often occurs during late winter (figs. 10 and 11). The secondary peak during late winter may be due to periods of winter thaw that can release pesticides from the surface and shallow subsurface to streams. Melt-water can rapidly transport herbicides through partially frozen soils to tile lines and streams in late winter (Gentry and others, 2000). Spring snowmelt has been shown to transport herbicides in runoff in field studies (Steinheimer and Scoggin, 2000). The daily changes in the frostline depth together with residual legacy of pesticide residues from previous year’s application may make pesticides available for transport even during the late winter.

Several pesticide compounds—EPTC, metribuzin, and trifluralin—were typically only detected in May and June, but dicamba, 2,4-D, and prometon concentration patterns did not necessarily have the largest concentration peaks in the spring. Dicamba is applied to broadleaf weeds later in the season, which would probably explain its highest detection rate in July. The compound 2,4-D did not show a seasonal trend and commonly was not detected. The pesticide 2,4-D is used on broadleaf weeds often throughout the growing season and in road rights-of-way which may indicate why it did not display a strong seasonal pattern. Prometon, a triazine herbicide, had relatively constant concentrations from June through October. The half-life of prometon is on the order of hundreds to thousands of days (almost an order of magnitude longer than atrazine). The nearly constant concentration of prometon is consistent given its long half-life and mode of application.

Most pesticides begin to break down or degrade by chemical and biological processes as soon as they are used, and the amount of the resulting degradates would be expected to follow a similar seasonal pattern as the parent pesticide compounds. Pesticide concentrations peak in May and June soon after application during periods of increased streamflow. Increased streamflow at this time of the year originates as runoff from rainfall. Parent pesticide concentrations decrease



EXPLANATION

- | | | | |
|------|---|-----------|--|
| (17) | Number of observations | — | Minimum reporting level for atrazine and cyanazine |
| ○ | Outlier data value more than 3 times the interquartile range outside the quartile | - - - - - | Minimum reporting level for deethylatrazine, deisopropylatrazine and cyanazine amide |
| * | Outlier data value less than or equal to 3 and more than 1.5 times the interquartile range outside the quartile | MCL | Maximum contaminant level |
| | Data value less than or equal to 1.5 times the interquartile range outside the quartile | | |
| | 75th percentile | | |
| | Median | | |
| | 25th percentile | | |

Figure 10. Monthly concentrations of selected triazine herbicides (atrazine, cyanazine, simazine) and degradates at basic-fixed sampling sites in the Eastern Iowa Basins study unit, 1996–98.

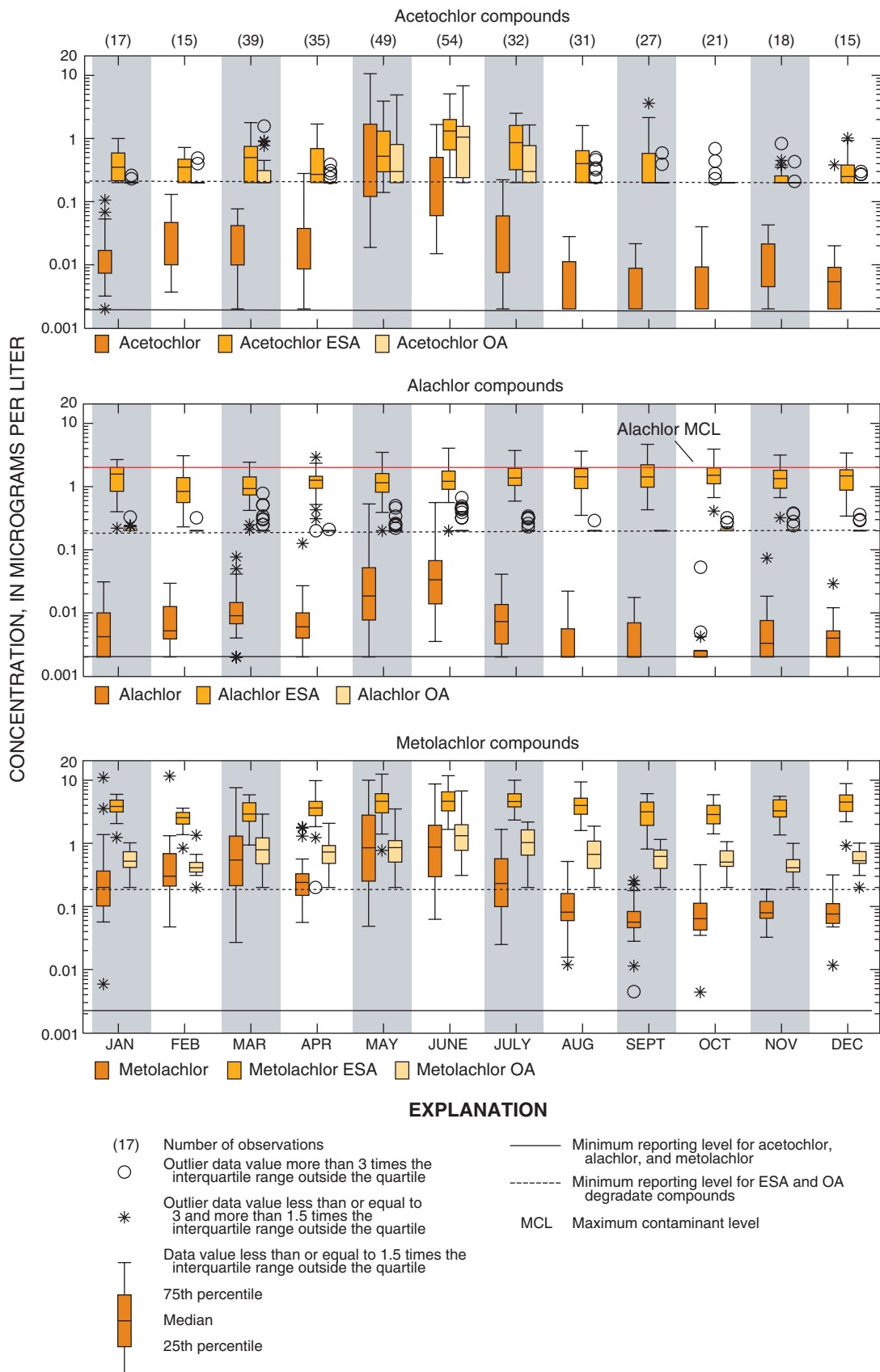


Figure 11. Monthly concentrations of selected chloroacetanilide herbicides (acetochlor, alachlor, metolachlor) and their degradates at basic-fixed sampling sites in streams in the Eastern Iowa Basins study unit, 1996–98.

in the Iowa River through the summer as summer rains decrease and vegetative cover increases. The seasonal pattern for the pesticide degradates typically mirrored that of the parent compounds, but degradates commonly remained at higher concentrations throughout the year (fig. 12). During late summer and early winter, concentrations of the pesticide degradates in the Iowa River generally were an order of magnitude higher than the parent compounds both in the upper part of the watershed near Rowan and near the mouth at Wapello.

Pesticides were still available for transport to streams during late winter and early spring at least 9 months after application. A secondary peak in concentrations of both pesticide parent and degradate compounds occurred in the Iowa River during late February through March when snow was melting and the upper soil layer was thawing (fig. 12).

Deethylatrazine concentrations generally follow the seasonal trend of the parent compound, but at slightly lower concentrations (fig. 10). However, in the late fall and winter, the median deethylatrazine

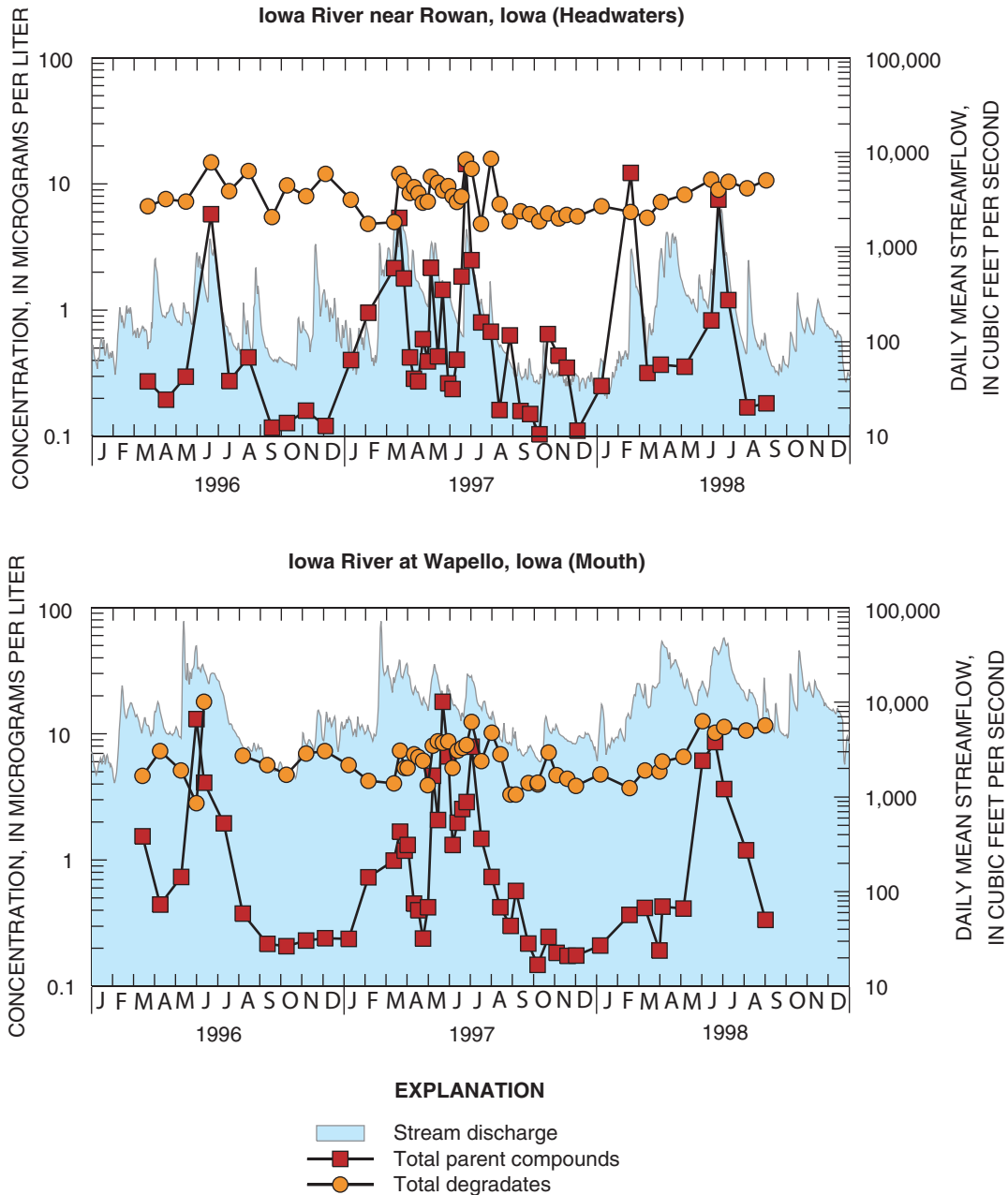


Figure 12. Seasonal variability of pesticides and pesticide degradates near the headwaters and the mouth of the Iowa River, 1996–98.

concentrations are higher than the median atrazine concentrations, but the difference is less than one-tenth of a microgram per liter (fig. 10). In contrast the chloroacetanilide herbicide degradates, metolachlor ESA, acetochlor ESA, and alachlor ESA, have significantly ($p < 0.05$) greater median concentrations than their parent compounds and do not vary seasonally as much as their parent compounds (fig. 11). The median concentrations of the degradates of the chloroacetanilide herbicides are much higher year round than their parent compounds. Concentrations of chloroacetanilide herbicide degradates during these periods indicate these compounds are particularly persistent in the environment. The higher concentrations of many of the degradates in the fall and winter months also indicate contributions from interflow or shallow ground water. Other studies indicate that pesticide degradates commonly occur in the alluvial aquifers adjacent to streams (Sadorf and Linhart, 2000; Savoca and others, 2000). These data seem to indicate that alachlor ESA is persistent and stable.

Seasonal variability in pesticides and pesticide degradates was documented in detail at 25 synoptic sites on streams that drained agricultural watersheds ranging in size from 310 to 1,500 km² (table 2). Samples were collected from these sites in August 1997 and May 1998 during base-flow conditions. The two most heavily applied chloroacetanilide herbicides (acetochlor and metolachlor) and their ethane sulfonic acid degradates were detected more frequently (fig. 13) and at greater concentrations during the spring (high base-flow conditions) than during the late summer (low base-flow conditions) (fig. 14). During late spring, pesticides from recent applications may be transported to the stream through short ground-water flow paths. Another potential source is from storage in streambanks. Rain events in late April and early May may result in high stream levels, which can produce a reverse gradient in adjacent alluvial aquifers transporting pesticides from the stream into the streambank. Water containing these pesticides subsequently drains back into the stream upon reestablishment of the normal hydrologic gradient during base-flow conditions (Squillace and others, 1993).

Differences between the detection rates and concentrations of triazine herbicides and their degradates were not significantly different between late spring (high) and late summer (low) base-flow conditions in streams (fig. 13 and 14). One exception was hydroxyatrazine. In addition to hydroxyatrazine,

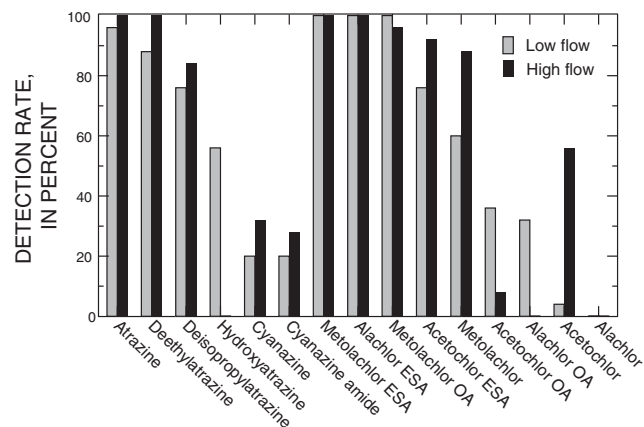


Figure 13. Detection rate of herbicides and herbicide degradates during low and high base-flow conditions at synoptic sampling sites on streams that drain agricultural watersheds in the Eastern Iowa Basins study unit.

acetochlor OA and alachlor OA were detected more frequently in the late summer than in late spring base-flow conditions. The structure of acetochlor OA and alachlor OA molecules are very similar and thus may behave in a similar manner in the environment. Hydroxyatrazine and alachlor OA were detected only in late summer. Chemical properties such as rate of formation and degradation may influence the timing of the occurrence of the oxanilic acid degradates. As discussed earlier, hydroxyatrazine may be formed in the soil, transported to the streambed on sediment, and remobilized by ground-water inflow primarily during summer.

In contrast to the most commonly used herbicides, insecticides generally were present only during the summer. A few insecticides that have been identified as posing a potential risk to aquatic invertebrates were detected in streams from May through September (fig. 15), the months when most application normally occurs. Carbofuran was the most frequently detected insecticide (16 percent of all the samples). Although detected in less than 20 percent of all samples, carbofuran was detected in 68 percent of the samples collected in June (fig. 15). When present, carbofuran concentrations generally were less than 0.80 µg/L. Chlorpyrifos was detected in about 7 percent of the samples. As with the other insecticides, chlorpyrifos was detected most frequently in June (about 30 percent of the samples). The highest concentration was 0.067 µg/L. Malathion was detected

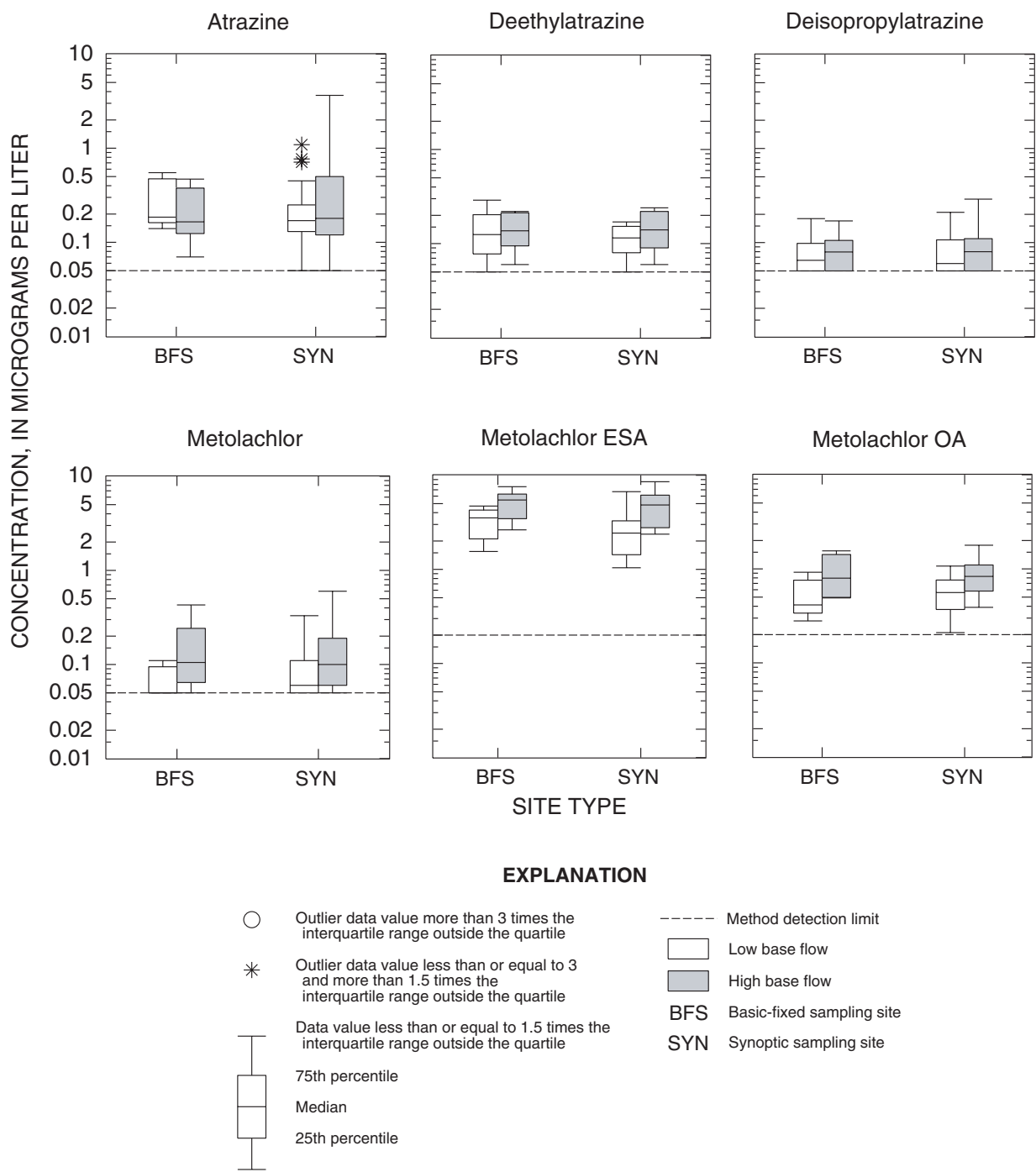


Figure 14. Concentrations of selected herbicides during low and high base-flow conditions in streams that drain agricultural watersheds in the Eastern Iowa Basins study unit.

in only three samples in spring and early summer at concentrations that ranged from 0.023 to 0.078 µg/L. In addition, insecticides such as diazinon and dieldrin that have been typically detected in urban areas in other NAWQA studies throughout the Nation (U.S. Geological Survey, 1999) were rarely detected (less than a 2 percent detection frequency) in the EIWA study unit. Most likely this is because the amount of

urban land where diazinon (a common urban insecticide) might be used in the EIWA study unit is small (1.8 percent). In general, the overall low detection rate and low concentrations of insecticides in streams of the EIWA study unit are probably due to their lower use (relative to herbicides), short half-life, and application during periods of reduced runoff.

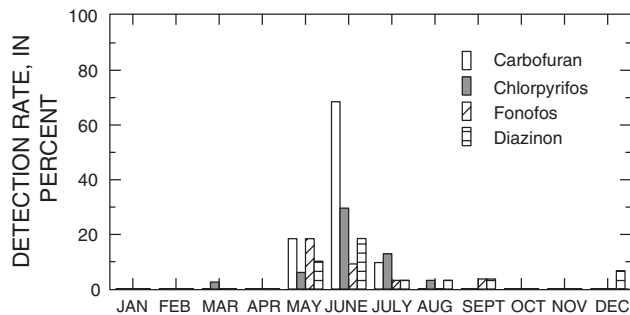


Figure 15. Monthly detection rate of selected insecticides in streams in the Eastern Iowa Basins study unit.

Spatial Variability

Numerous factors such as soil type, pesticide soil-water partition coefficients, application rates, and pesticide use all affect the spatial variability of pesticide concentrations in streams in eastern Iowa. A detailed analysis of all variables that can affect this spatial variability was beyond the scope of this report. However, statistically significant differences for concentrations of the triazines and the chloroacetanilide compounds were shown between basic-fixed sites (figs. 16 and 17) that may be related to topographic and geologic differences in landform regions. Median concentrations for atrazine and cyanazine were statistically larger for sites at the Skunk River at Augusta and Old Mans Creek near Iowa City than the other sites. The Skunk River at Augusta site has 74.7 percent of its drainage and the Old Mans Creek near Iowa City site has 100 percent of its drainage within the Southern Iowa Drift Plain.

Metolachlor concentrations were significantly ($p < 0.05$) larger at the South Fork Iowa River near New Providence and Iowa River at Marengo sites than at the other sites (fig. 17). The median metolachlor concentration for the South Fork Iowa River site (100 percent drainage on the Des Moines Lobe) was $0.50 \mu\text{g/L}$ and the median metolachlor concentration for the Iowa River at Marengo site (44.5 percent drainage on the Des Moines Lobe, 37.2 percent on the Iowan Surface, and 18.3 percent on the Southern Iowa Drift Plain) was $0.358 \mu\text{g/L}$. Median concentrations of acetochlor were significantly ($p < 0.05$) larger at the South Fork Iowa River ($0.036 \mu\text{g/L}$), Iowa River at Marengo ($0.036 \mu\text{g/L}$), and Skunk River at Augusta ($0.040 \mu\text{g/L}$) sites than at the other sites (fig. 17).

Based solely on agricultural land use, it is somewhat surprising that there are significant concentration differences among the sampling sites. One possible

explanation for differences among sites is difference in herbicide use between landform regions. Stoltenberg and Pope (1990) reported that atrazine was applied to only 25 percent of the corn in north-central Iowa in contrast to 69 percent of the corn in southeastern Iowa during the 1980's. Application rates also were less in north-central Iowa in areas with lower permeability till soils that contained greater organic carbon content because of farmers' concern that "carryover" of atrazine may damage subsequent soybean crops. Also, in response to the detection of atrazine in ground water, atrazine management areas were established in northeastern Iowa in areas where bedrock aquifers are close to the land surface (Iowa Department of Agriculture and Land Stewardship, 1999). No more than 1.4 kg of atrazine may be applied per hectare per year (1.5 lb per acre per year) in these management areas. The atrazine management areas correspond closely with the Iowan Karst subregion (fig.18).

Two closely related factors, herbicide use and degradation properties of the herbicides, may account for the generally greater detection rate and larger concentrations of triazine compounds in streams draining soils developed on windblown loess (Southern Iowa Drift Plain) than in streams draining till soils (Des Moines Lobe and Iowan Surface). Because of soil properties, triazine pesticide-use rates are apparently less in areas with predominantly till soils (Stoltenberg and Pope, 1990). These soils have high organic carbon content with pH values near 7.0 that decreases the degradation of the triazines and helps to retain (carry over) atrazine and cyanazine in the soil. Cyanazine sorption has been correlated with fine soil texture and greater organic carbon content (Reddy and others, 1997). Alachlor, metolachlor, and acetochlor probably were used to offset reduced triazine pesticide use in areas with till soils.

Median alachlor concentrations were low at all sites (generally less than $0.1 \mu\text{g/L}$) and probably reflected the relatively low use in the study unit. However, the median alachlor concentrations were significantly higher ($p < 0.05$) at two sites—Wapsipinicon River at Tripoli and Wapsipinicon River at Dewitt (fig. 17) than at the other sites. Because the Wapsipinicon River drains part of the atrazine management area, greater alachlor concentrations may be due to its preferential use.

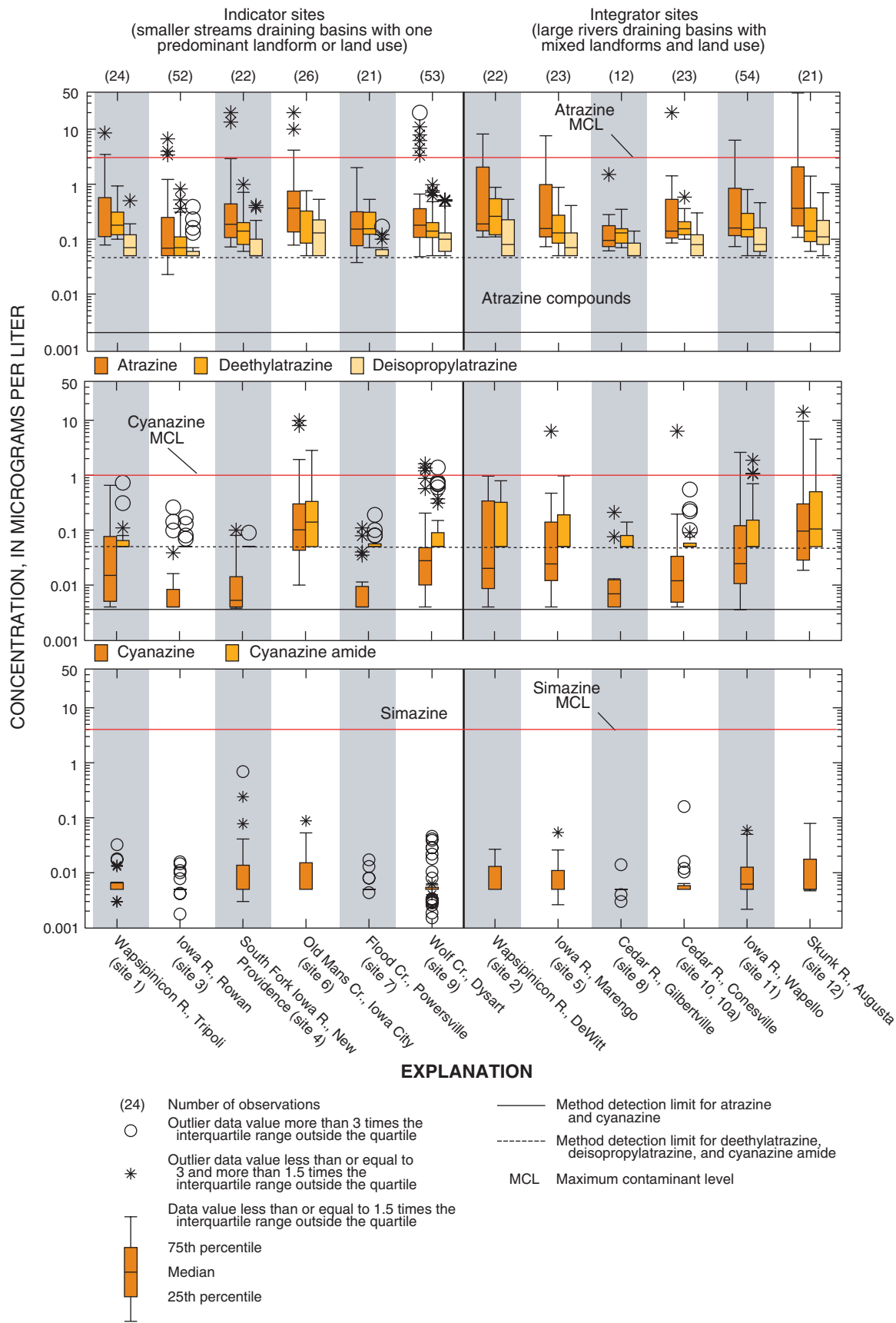


Figure 16. Concentrations of selected triazine herbicides (atrazine, cyanazine, simazine) and degradates at the basic-fixed sampling sites in the Eastern Iowa Basins study unit, 1996–98.

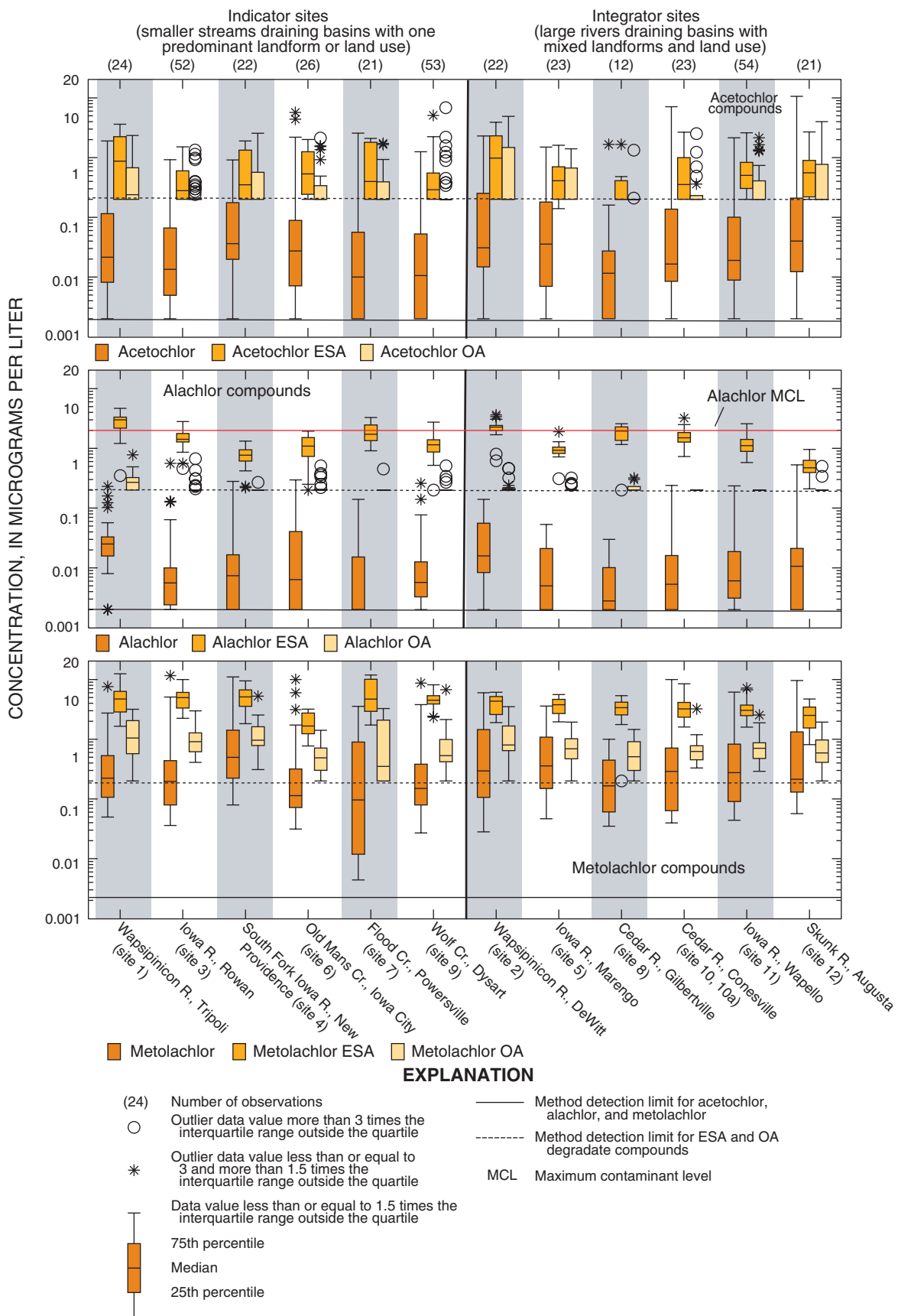


Figure 17. Concentrations of selected chloroacetanilide herbicides (acetochlor, alachlor, metolachlor) and their degradates at the basic-fixed sampling sites in the Eastern Iowa Basins study unit, 1996–98.

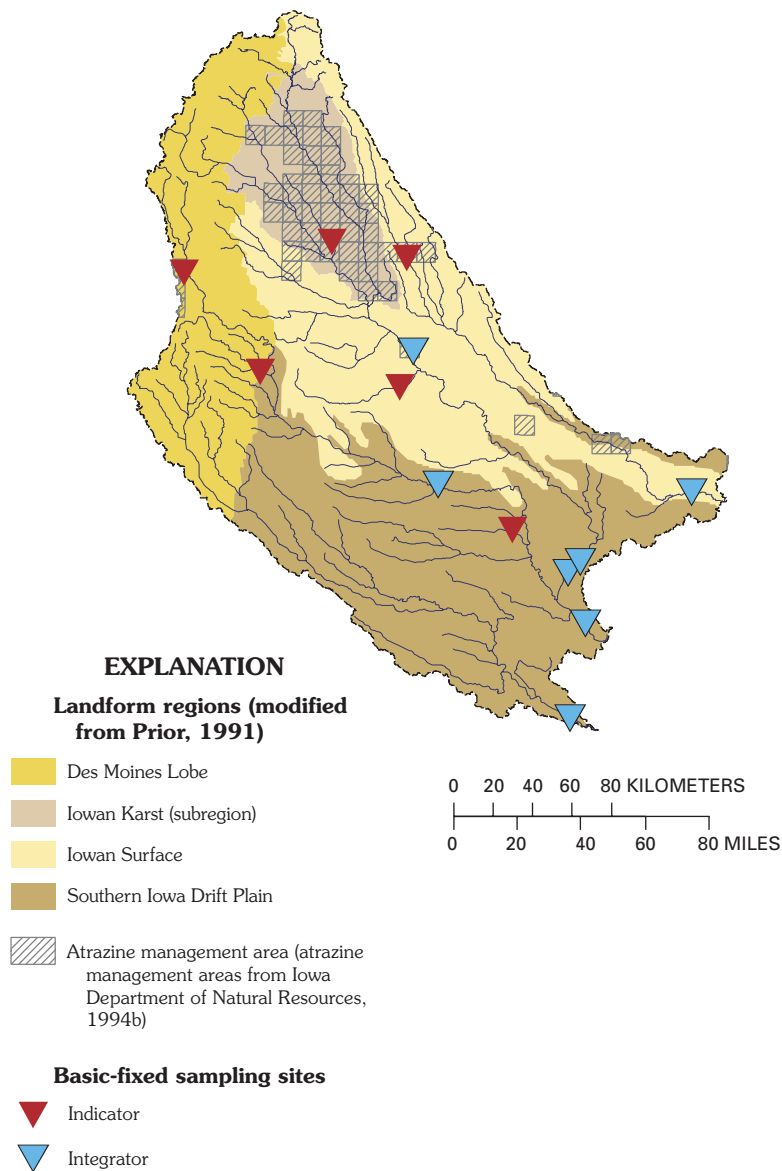


Figure 18. Atrazine management areas in the Eastern Iowa Basins study unit.

The occurrence of degradates and the ratio of degradate to parent compound were substantially different for the triazines than for the chloroacetanilide compounds. Concentrations of the triazine degradates tended to follow the pattern of the parent compounds—highest concentrations during the early summer followed by decreasing concentrations during the late summer and fall (fig. 10). However, concentrations of the triazine degradates were lower than their parent compounds except in the fall and winter when they were slightly higher. In contrast, the ESA and OA degradates of alachlor, acetochlor, and metolachlor

were present in higher concentrations than their parent compounds throughout the year (fig. 11).

Synoptic sampling during high and low base-flow conditions at 25 sites confirmed the spatial pattern seen at the monthly sampling (basic-fixed) sites. Much of the spatial variability during base-flow conditions was related to landform types and their geologic and hydrologic differences. Overall, pesticide detections and concentrations were different in the Southern Iowa Drift Plain than in the Des Moines Lobe or the Iowan Surface. The main difference, with two exceptions, is that the triazine herbicides and their

degradates were present in significantly greater concentrations in streams of the Southern Iowa Drift Plain than in streams of the two other physiographic areas (table 6). The exceptions were that acetochlor and acetochlor OA had significantly greater concentra-

tions in the Southern Iowa Drift Plain streams during high base-flow conditions and low base-flow conditions, respectively.

Results of sampling in the EIWA study unit from 1996 through 1998 concur with previous investi-

Table 6. Triazine and chloroacetanilide pesticide and pesticide degradates during low (August 1997) and high (May 1998) base flow at the synoptic sampling sites in the Eastern Iowa Basins study unit

[$\mu\text{g/L}$, micrograms per liter; bold text indicates concentrations from sites in one or more landforms are significantly different; <, less than]

Constituent	Base-flow type	Landforms (defined by Prior, 1991)					
		Des Moines Lobe (7 sites)		Iowan Surface (11 sites)		Southern Iowa Drift Plain (7 sites)	
		Detection rate (Percent)	Median concentration ($\mu\text{g/L}$)	Detection rate (Percent)	Median concentration ($\mu\text{g/L}$)	Detection rate (Percent)	Median concentration ($\mu\text{g/L}$)
Acetochlor	Low	0	<0.05	9	<0.05	0	<0.05
	High	57	.06	27	<.05	100	.12
Acetochlor ESA	Low	86	.41	64	.27	86	.45
	High	86	.63	91	.65	100	.76
Acetochlor OA	Low	29	<.20	9	<.20	86	.53
	High	14	<.20	9	<.20	0	<.20
Alachlor	Low	0	<.05	0	<.05	0	<.05
	High	0	<.05	0	<.05	0	<.05
Alachlor ESA	Low	100	1.4	100	1.9	100	.90
	High	100	1.1	100	1.6	100	1.0
Alachlor OA	Low	29	<.20	27	<.20	43	<.20
	High	0	<.20	27	<.20	0	<.20
Atrazine	Low	100	.17	91	.13	100	.25
	High	100	.15	100	.12	100	.50
Deisopropylatrazine	Low	43	<.05	82	.06	100	.13
	High	43	<.05	100	.08	100	.17
Deethylatrazine	Low	57	.06	100	.12	100	.14
	High	100	.07	100	.17	100	.21
Hydroxyatrazine	Low	14	<.05	55	.27	100	1.0
	High	0	<.05	0	<.05	0	<.05
Cyanazine	Low	14	<.05	9	<.05	43	<.05
	High	14	<.05	9	<.05	86	.16
Cyanazine amide	Low	0	<.05	0	<.05	71	.07
	High	14	<.05	0	<.05	57	.09
Metolachlor	Low	57	.06	46	<.05	86	.07
	High	100	.20	73	.07	100	.17
Metolachlor ESA	Low	100	4.0	100	2.5	100	1.4
	High	100	5.1	100	5.0	100	2.8
Metolachlor OA	Low	100	.75	100	.45	100	.49
	High	100	.78	100	.98	100	.81

gations that found seasonal patterns of concentrations and occurrences of pesticides in agricultural streams tend to repeat each year and correspond to patterns of application, streamflow, and ground-water flow (U.S. Geological Survey, 1999). The seasonal pattern of the commonly applied herbicides such as atrazine and alachlor in midwestern rivers is well documented (Larson and others 1997; Richards and Baker, 1991; Goolsby and Battaglin, 1993). Concentrations are generally low in the late fall and winter and peak in the spring and early summer. In general, increased concentrations of herbicides in streams draining agricultural areas can occur within a few days to a few weeks, depending on the timing and number of rainfall events and the size of the drainage basin (Larson and others, 1997). The first runoff-inducing rain event after the application of pesticides potentially can move substantial amounts of the pesticide to surface waters (Schottler and others, 1994; Larson and others, 1997; Goolsby and Battaglin, 1993).

RELEVANCE OF PESTICIDES IN STREAMS

Pesticides have been a very important tool in the control of unwanted vegetation in crops, road rights-of-way, lawns, and other urban areas and in controlling insects and other biological pests in both agricultural and urban areas. However, transport of excess pesticides to streams may have unintended effects on humans that use the rivers and streams as a source of water supply and to aquatic organisms living in the stream. A brief overview of the environmental significance of pesticides in eastern Iowa streams is discussed in this section. Pesticide relevance will be discussed in relation to drinking-water criteria for human-health effects and in relation to results from toxicological research on algae, benthic invertebrates, and fish. Additional discussion on the effects on human health and on aquatic life in streams can be found in Larson and others (1997), and national primary drinking-water regulations are available for individual pesticide compounds from the U.S. Environmental Protection Agency (1995).

Human Health

During the sampling period of this study, 1996–98, the city of Iowa City utilized water directly from

the Iowa River as part of their municipal water supply. A number of smaller communities use water from reservoirs as source of supply. During the 3 years of this study, no drinking-water criteria (on a yearly average) were exceeded, but MCL's were exceeded in individual samples for several compounds. MCL concentrations in individual samples were most frequently exceeded for the triazine herbicides atrazine (10 percent of the samples) and cyanazine (3.8 percent of the samples). Although atrazine concentrations exceeded the MCL in only 10 percent of the samples, all exceedances occurred in 3 months: May, June, and July (fig. 10). Storage of spring runoff in reservoirs potentially can extend the seasonally high spring pesticide concentrations into the summer and lengthen the potential annual exposure to these compounds (Kalkhoff, 1993). Pesticide concentrations exceed 1.0 µg/L in some Iowa reservoirs used for municipal water supplies (Miller and Kennedy, 1995) during the winter, 6 to 9 months after application.

Acetochlor, a herbicide that was conditionally registered for use beginning in 1994, was frequently detected, but in most samples (75 percent) at concentrations less than 0.1 µg/L. Acetochlor concentrations did not exceed the USEPA 2.0-µg/L annual mean concentration registration requirement at any site but did exceed this concentration in about 3 percent of the individual samples. The maximum concentration (10.6 µg/L) measured during the study exceeded the concentration that would trigger requirements for biweekly sampling for water-supply systems (U.S. Environmental Protection Agency, 1994a).

Only limited research has been conducted on the acute and chronic human and environmental effects of pesticide degradates. In one study (Heydens and others, 2000), alachlor was found to break down into at least one less toxic compound, alachlor ESA.

Natural infiltration of stream water may transport pesticides to shallow alluvial aquifers during the spring runoff during rising river stages (Squillace, 1996). In addition, pumping of municipal wells located near rivers can induce additional infiltration of river water into the adjacent alluvial aquifers (Schulmeyer and Schnoebelen, 1998; Boyd, 2000 and 2001; Savoca and others, 2002). Many communities in Iowa use ground water that is pumped from alluvial aquifers located adjacent to rivers and streams because this is a dependable source of supply. With the exception of karst bedrock, total herbicide concentrations (sum of the concentrations of all compounds analyzed) were

greatest from municipal wells pumping from alluvial aquifers in Iowa in 1995 (Kolpin and others, 1997).

Aquatic Life

Pesticide concentrations in eastern Iowa and southern Minnesota streams may occasionally reach levels that have been identified as affecting algae, macroinvertebrates, and fish. In contrast to humans who are generally exposed to pesticides through ingestion of water, aquatic organisms living in streams are continually exposed to any pesticides occurring in the stream. The effects of this exposure is not fully understood. A large amount of research has investigated the effects of pesticides on aquatic organisms; several of these studies are referenced in the following discussion.

The direct effects of pesticides on algae were not investigated during this study but may be inferred on the basis of concentrations found to affect algae in other investigations. The concentration of most pesticides in sampled streams in the EIWA study unit probably was not high enough to be acutely toxic to algae during 1996–98. However, similar seasonally high concentrations have been shown to temporarily reduce photosynthetic activity or alter the community structure. In field mesocosm studies, phytoplankton and macrophytes were reduced after atrazine exposures greater than 20 µg/L, but populations were quickly reestablished (Solomon and others, 1996). Effects were ecologically important only at exposures of 50 µg/L or greater (Solomon and others, 1996). The atrazine concentration was 20 µg/L or more in only five samples (1.2 percent) and approached 50 µg/L (Appendix 2) in only one sample during this study. Alachlor has been shown to affect algal biomass at concentrations of 10 µg/L or greater but did not significantly affect biomass at a concentrations of 1 µg/L (Spawn and others, 1997). The maximum alachlor concentration in samples described in this report was less than 1.0 µg/L.

Agricultural activity in a watershed was a factor accounting for differences in benthic invertebrate assemblages in EIWA streams (Brigham and Sadorf, 2001). However, agriculture's effect on habitat, nutrient concentrations, or pesticide concentrations as the primary factor in the differing community structure could not be determined with the available data.

The possible effects of concentrations of pesticides determined for this report on fish communities is unclear. Physical characteristics (stream size) and nutrient enrichment (total phosphorus and organic carbon concentrations) were more significant determinants of fish community structure than pesticide concentrations (Sullivan, 2000). A subsequent study on the Cedar River (Phillips and Summerfelt, 2001) indicated that acetochlor, deethylatrazine, metolachlor, and parathion in water during April and May 1998 and 1999 did not affect the cholinesterase (ChE) activity in larval walleye. No effect on ChE activity was noted even though the parathion concentration exceeded U.S. Environmental Protection Agency (1999) aquatic health guidelines in one sample in 1999 (Phillips and Summerfelt, 2001). However, another study has shown that exposures to insecticides that exceeded U.S. Environmental Protection Agency (1999) aquatic health guidelines over a several months have been linked to depressed ChE in common carp (*Cyprinus carpio*) (Gruber and Munn, 1998).

Laboratory research has suggested that atrazine concentrations as small as 0.1 µg/L affected some frogs (Hayes and others, 2002). When exposed to increasing amounts of atrazine, as many as 20 percent of the frogs exposed during their early development produced multiple sex organs or had both male and female organs (Hayes and others, 2002). In this report, more than 50 percent of the water samples collected in April and more than 75 percent of the samples collected in May contained atrazine concentration greater than 0.1 µg/L (fig. 10), and maximum concentrations in May were nearly 50 µg/L.

SUMMARY AND CONCLUSIONS

A water-quality assessment of streams in four major watersheds in eastern Iowa and parts of southern Minnesota was conducted from 1996 through 1998 as part of the U.S. Geological Survey's NAWQA Program. Samples were collected in the EIWA study unit, an area that encompasses about 50,500 km² (19,500 mi²) and includes the Wapsipinicon, Cedar, Iowa, and Skunk watersheds. Twelve basic-fixed sites were sampled monthly during the first year of the study (March 1996 through March 1997) and 11 basic-fixed sites were sampled after March 1997. The basic-fixed sites ranged from 320 to 32,400 km² (124 to 12,500 mi²) in size. Three basic-fixed sites (Iowa

River at Rowan, Wolf Creek near Dysart, and Iowa River at Wapello) were intensively sampled from April 1997 through March 1997. Additional samples were collected during floods to define pesticide concentrations through the full range of streamflow that occurred during the study. Samples were analyzed for 82 pesticide parent compounds and 10 pesticide degradate compounds. More than 350 samples were collected for pesticide analysis at the basic-fixed sites. To better define spatial variability, samples were collected from 25 sites during low base-flow conditions during August 1997 and during high base-flow conditions in May 1998.

The most commonly detected herbicides were those most heavily used on crops. Atrazine and metolachlor were detected in all surface-water samples. Acetochlor, alachlor, and cyanazine were detected in more than 70 percent of the samples. Seventy-six percent of the atrazine samples exceeded 0.1 µg/L with almost 60 percent in the 0.1 to 1.0 µg/L range. About 10 percent of the samples exceeded the atrazine MCL for drinking water of 3.0 µg/L. Less frequently detected pesticides (detected in 30 percent or less of the samples) such as EPTC, trifluralin, metribuzin, carbofuran, dicamba, and 2,4-D were applied to crops in Iowa at a rate of only 0.6 to 30 percent of the amount applied for atrazine alone.

Many pesticides are used in both non-row-crop agriculture and urban settings, but three herbicides—prometon, tebuthiuron, and triclopyr—used almost exclusively in non-row-crop and urban settings were detected. Prometon was detected in more than 80 percent of the samples, but at very low concentrations (less than 0.1 µg/L). Prometon's chemical persistence may explain its relatively high detection rate relative to its low use. Tebuthiuron was detected in 7 percent and triclopyr was detected in 1 percent of the samples.

Insecticides were rarely detected, and when they were detected, concentrations were near the method detection limit. Carbofuran was the most commonly detected insecticide (16 percent of the samples). Other insecticides were detected in less than 10 percent of the samples.

The pesticide degradates were some of the most frequently detected pesticide compounds in the study unit and on average constituted the majority of the pesticide residue in water samples. Metolachlor ESA, alachlor ESA, metolachlor OA, and acetochlor ESA were detected in more than 75 percent of the samples.

On average, approximately 83 percent of the total pesticide mass (parent and degradate compounds) can be accounted for by the 10 common degradates of acetochlor, alachlor, atrazine, cyanazine, and metolachlor. Median concentrations for pesticide degradate compounds were higher than those of their parent compounds. Median concentrations for the degradates ranged from 0.07 to 3.7 µg/L compared to median concentrations for their parent compounds that ranged from 0.01 to 0.22 µg/L. Concentrations of metolachlor ESA, alachlor ESA, and acetochlor ESA were often more than 10 times greater than their parent compounds.

Mixtures of pesticides were common. At least one pesticide degradate (metolachlor ESA) was present in each water sample analyzed. Approximately 68 percent of all the samples collected contain four or more pesticide degradates, and approximately 17 percent of all samples contain seven or more pesticide degradates. As in the case of the degradates, the parent pesticide compounds were commonly found together. Two parent pesticide compounds, atrazine and metolachlor, were detected in all of the samples analyzed. Two or more parent pesticide compounds were detected in all samples, and five or more compounds were detected in 50 percent of the samples.

Concentrations of pesticide compounds in streams follow strong seasonal patterns. The highest herbicide concentrations occurred in the spring (May and June) during spring runoff events. A secondary peak in pesticide concentrations occurred in late winter, typically in March, at all sites for the chloroacetanilides and triazines (with the exception of prometon). This secondary peak in pesticide concentrations during late winter may be due to early thaw that can release pesticides from the soil surface and shallow subsurface to surface waters.

The detection rates and concentrations of most triazine herbicides and their degradates were not significantly different between late spring and late summer base-flow conditions in streams. Exceptions were hydroxyatrazine, acetochlor OA, and alachlor OA. These three degradates were detected most frequently in late summer during base-flow conditions. Hydroxyatrazine and alachlor OA were detected only in late summer. Hydroxyatrazine may be formed in the soil, transported to the streambed on sediment, and remobilized by ground-water inflow primarily during summer. Chemical properties such as rate of

formation and degradation may influence the timing of the occurrence of the oxanilic acid degradates.

The pattern of occurrence and concentration was found to differ between the degradates of triazine and chloroacetanilide herbicides. The triazine herbicide degradates tended to follow a monthly concentration pattern similar to their parent compounds, but the concentrations were lower than their parent compounds, except in the fall and winter. In contrast, the chloroacetanilide degradates were present in greater concentrations than their parent compounds throughout the year.

Pesticide compounds varied between landform regions. The triazine herbicides and their degradates were present in greater concentrations (statistically significant) in streams in the Southern Iowa Drift Plain than in streams in the Des Moines Lobe or the Iowan Surface. Much of the variability may be related to the geologic and hydrologic differences between landforms. Because of differences in soil properties, triazine pesticide-use rates are less in areas with predominantly till soils such as the Des Moines Lobe and Iowan Surface compared to areas with windblown loess soils. The alternative use of other classes of herbicides may account for greater occurrence and concentration of some chloroacetanilide herbicides in the Des Moines Lobe and the Iowan Surface.

The presence of pesticides in streams may seasonally affect municipalities that use surface water in eastern Iowa and southern Minnesota. Although the annual average concentrations did not exceed the MCL, concentrations of atrazine and cyanazine in individual samples occasionally exceed the MCL in spring and early summer. Wells used for municipal supply located near streams may induce infiltration from the stream into the alluvial aquifers and subsequently into the water supply. Pesticides present in the stream may be transported through the alluvial aquifer to the water-supply wells. The possible effects of pesticides in streams to aquatic organisms are not known. Concentrations may occasionally reach levels that have been identified as affecting algae, fish, and amphibians.

The results presented in this report provide an assessment of the presence of pesticide compounds that were commonly used during and possibly several years preceding the study period 1996–98. However, agricultural practices continue to evolve with emphasis both on the use of less pesticides and on the use of genetically modified crops that are resistant to insects

and glyphosate herbicides. Commonly used herbicides, like metolachlor, are being reformulated to be more effective and require less product, and a number of products, for example cyanazine, will no longer be used. Because pesticides are transported to streams and because pesticides may affect drinking-water supplies and aquatic organisms, there is a need to continue monitoring currently used pesticides and to monitor new compounds that are applied in the environment.

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APPENDIX

Appendix 1. Herbicide and insecticide target analytes, method detection limits, and drinking-water standards

[Concentrations in micrograms per liter, MCL, maximum contaminant level; HA, health advisory; HPLC, high performance liquid chromatography, GC/MS, gas chromatography/mass spectrometry; --, no regulation or guideline]

Compound	Trade name(s)	Analysis method	Method detection limit (µg/L)	Regulation or guideline for drinking water (MCL or HA) (µg/L)
Herbicides				
2, 4-D	2, 4-D and others	HPLC	0.035	¹ 70
2,4-DB	Butoxone	HPLC	0.035	--
2,4,5-T	Line Rider, Weedone	HPLC	0.035	70
2,4,5-TP	Silvex	HPLC	0.021	¹ 50
2,6-Diethylaniline	Degradate of alachlor	GC/MS	0.003	--
Acetochlor	Harness	GC/MS	0.002	--
Acetochlor ESA (ethane sulfonic acid)	Degradate of acetochlor	HPLC	0.20	--
Acetochlor OA (oxanilic acid)	Degradate of acetochlor	HPLC	0.20	--
Acifluorfen	Blazer, Tackle	HPLC	0.035	--
Alachlor	Lasso	GC/MS	0.002	¹ 2
Alachlor ESA (ethane sulfonic acid)	Degradate of alachlor	HPLC	0.20	--
Alachlor OA (oxanilic acid)	Degradate of alachlor	HPLC	0.20	--
Atrazine	Aatrex	GC/MS	0.001	¹ 3
Benfluralin	Balan, Benefin	GC/MS	0.002	--
Bentazon	Basagran	HPLC	0.014	20
Bromacil	Bromax 90, Urox B	HPLC	0.035	90
Bromoxynil	Buctril, Brominal	HPLC	0.035	--
Butylate	Sutan+	GC/MS	0.002	350
Chloramben	Amiben	HPLC	0.011	100
Clopyralid	Lontrel	HPLC	0.050	--
Cyanazine	Bladex	GC/MS	0.004	1
Cyanazine amide	Degradate of cyanazine	HPLC	0.20	--
Dacthal	Dacthal	GC/MS	0.002	4,000
Deethylatrazine	Degradate of atrazine	GS/MS	0.002	--
Deisopropylatrazine	Degradate of atrazine	GS/MS	0.20	--
Dicamba	Banvel	HPLC	0.035	200
Dichlobenil	Casoron	HPLC	0.020	--
Dichlorprop	2,4-DP	HPLC	0.032	--
Dinoseb	Basanite and others	HPLC	0.035	¹ 7
Diuron	Diurex and others	HPLC	0.020	10
EPTC	Eptam	GC/MS	0.002	--
Ethalfuralin	Sonalan	GC/MS	0.004	--
Fenuron	Beet-Kleen	HPLC	0.013	--
Fluometuron	Cotoran	HPLC	0.035	90
Hydroxyatrazine	Degradate of atrazine	HPLC	0.20	--
Linuron	Lorox	GC/MS	0.002	--
MCPA	MCPA and others	HPLC	0.050	10
MCPB	Thistrol	HPLC	0.050	--
Metolachlor	Dual	GC/MS	0.002	100

Appendix 1. Herbicide and insecticide target analytes, method detection limits, and drinking-water standards
—Continued

[Concentrations in micrograms per liter, MCL, maximum contaminant level; HA, health advisory; HPLC, high performance liquid chromatography, GC/MS, gas chromatography/mass spectrometry; --, no regulation or guideline]

Compound	Trade name(s)	Analysis method	Method detection limit (µg/L)	Regulation or guideline for drinking water (MCL or HA) (µg/L)
Herbicides—Continued				
Metolachlor ESA (ethanesulfonic acid)	Degradate of metolachlor	HPLC	0.20	--
Metolachlor OA (oxanilic acid)	Degradate of metolachlor	HPLC	0.20	--
Metribuzin	Lexone, Sencor	GC/MS	0.004	200
Molinate	Ordram	GC/MS	0.004	--
Napropamide	Devrinol	GC/MS	0.003	--
Neburon	Neburex, Neburon	HPLC	0.015	--
Norflurazon	Evital, Zorial	HPLC	0.024	--
Oryzalin	Surflan	HPLC	0.019	--
Pebulate	Tillam	GC/MS	0.004	--
Pendimethalin	Prowl, Stomp	GC/MS	0.004	--
Picloram	Tordon	HPLC	0.050	¹ 500
Prometon	Pramitol	GC/MS	0.018	100
Pronamide	Kerb	GC/MS	0.003	50
Propachlor	Ramrod	GC/MS	0.007	90
Propanil	Stampede	GC/MS	0.004	--
Propham	IPC	HPLC	0.035	100
Simazine	Princep, Aquazine	GC/MS	0.005	¹ 4
Tebuthiuron	Spike, Graslan	GC/MS	0.010	500
Terbacil	Sinbar	GC/MS	0.007	90
Thiobencarb	Bolero	GC/MS	0.002	--
Triallate	Far-Go	GC/MS	0.001	--
Triclopyr	Garlon	HPLC	0.050	--
Trifluralin	Treflan and others	GC/MS	0.002	5
Insecticides				
1-Naphthol	Degradate of carbaryl	HPLC	0.007	--
3-OH-carbofuran	Degradate of carbofuran	HPLC	0.014	--
Aldicarb	Temik	HPLC	0.016	¹ 3
Aldicarb sulfone	Degradate of aldicarb	HPLC	0.016	¹ 2
Aldicarb sulfoxide	Degradate of aldicarb	HPLC	0.021	¹ 4
Azinphos-methyl	Guthion	GC/MS	0.001	--
Carbaryl	Sevin	GC/MS	0.003	700
Carbofuran	Furadan	GC/MS	0.003	¹ 40
Chlorothalonil	Bravo	HPLC	0.035	--
Chlorpyrifos	Dursban, Lorsban	GS/MS	0.004	20
p,p'-DDE	Degradate of DDT	GC/MS	0.006	--
Diazinon	Diazinon and others	GC/MS	0.002	0.6
Dieldrin	Panoram D-31	GCMS	0.001	--
Disulfoton	Disyston and others	GC/MS	0.017	0.3
Esfenvalerate	Asana	HPLC	0.019	--

Appendix 1. Herbicide and insecticide target analytes, method detection limits, and drinking-water standards
—Continued

[Concentrations in micrograms per liter, MCL, maximum contaminant level; HA, health advisory; HPLC, high performance liquid chromatography, GC/MS, gas chromatography/mass spectrometry; --, no regulation or guideline]

Compound	Trade name(s)	Analysis method	Method detection limit (µg/L)	Regulation or guideline for drinking water (MCL or HA) (µg/L)
Ethoprop	Mocap	GC/MS	0.003	--
Insecticides—Continued				
Fonofos	Dyfonate	GC/MS	0.003	10
alpha-HCH	Lindane (impurity)	GC/MS	0.002	--
gamma-HCH	Lindane	GC/MS	0.011	¹ 0.2
Malathion	Malathion and others	GC/MS	0.005	200
Methiocarb	Mesurool	HPLC	0.026	--
Methomyl	Lannate and others	HPLC	0.017	200
Methyl-parathion	Pennacap-M	GC/MS	0.006	2
Oxamyl	Vydate	HPLC	0.018	¹ 200
Parathion	Alkron	GC/MS	0.004	--
cis-Permethrin	Ambush, Pounce	GC/MS	0.005	--
Phorate	Thinet and others	GC/MS	0.002	--
Propargite	Comite, Omite	GS/MS	0.013	--
Propoxur	Baygon	HPLC	0.035	3
Terbufos	Counter	GC/MS	0.013	0.9

¹U.S. Environmental Protection Agency (USEPA) maximum contaminant level or health advisory level for drinking water (Nowell and Resek, 1994).

Appendix 2. Statistical summary of pesticides and pesticide degradates at the basic-fixed sampling sites in the Eastern Iowa Basins, 1996–98

[<, less than indicated detection level; MCL, U.S. Environmental Protection Agency maximum contaminant level; --, MCL not established; * includes estimated concentrations less than the method reporting limit]

Constituent	Number of samples	Detection rate, in percent	Percentage of samples exceeding MCL	Concentration, in micrograms per liter			
				Mean	Median	Minimum	Maximum
Wapsipinicon River near Tripoli, Iowa (site 1; fig. 1, table 2)							
2,6-Diethylaniline	24	0.0	--	<.003	<.003	<.003	<.003
Acetochlor	24	86.4	0.0	0.15	.022	<.002	1.9
Acetochlor ESA	22	72.7	--	1.2	.87	<.20	3.6
Acetochlor OA	22	54.5	--	.50	.24	<.20	2.4
Alachlor	24	90.9	0.0	.044	.025	<.002	.231
Alachlor ESA	22	100	--	2.79	3.0	.35	4.67
Alachlor OA	22	68.2	--	.30	.27	<.20	.78
alpha-HCH	24	0.0	0.0	<.002	<.002	<.002	<.002
Atrazine	24	100	9.1	.83	.15	.078	8.6
Azinphos-methyl	24	0.0	0.0	<.001	<.001	<.001	<.001
Benfluralin	24	0.0	--	<.002	<.002	<.002	<.002
Butylate	24	0.0	0.0	<.001	<.002	<.002	<.002
Carbaryl	24	0.0	0.0	<.003	<.003	<.003	<.003
Carbofuran	24	22.7	0.0	.04	<.003	<.003	.35
Chlorpyrifos	24	9.1	0.0	<.004	<.004	<.004	.022
cis-Permethrin	24	0.0	--	<.005	<.005	<.005	<.005
Cyanazine	24	81.8	0.0	.076	.015	<.004	.653
Cyanazine-amide	23	21	--	.10	<.05	<.05	.73
Dacthal	24	0.0	--	<.002	<.002	<.002	<.002
Deethylatrazine	23	100	--	.24	.18	.10	.93
Deisopropylatrazine	21	78.2	--	.09	.07	<.05	.50
Diazinon	24	0.0	0.0	<.002	<.002	<.002	<.002
Dieldrin	24	0.0	0.0	<.001	<.001	<.001	<.001
Disulfoton	24	0.0	0.0	<.017	<.017	<.017	<.017
EPTC	24	22.7	--	.005	<.002	<.002	.088
Ethalfuralin	24	0.0	--	<.004	<.004	<.004	<.004
Ethoprophos	24	0.0	--	<.003	<.003	<.003	<.003
Fonofos	24	0.0	0.0	<.003	<.003	<.003	<.003
Hydroxyatrazine	22	31.8	--	.30	<.20	<.20	.75
Lindane	24	0.0	0.0	<.004	<.004	<.004	<.004
Linuron	24	0.0	--	<.002	<.002	<.002	<.002
Malathion	24	0.0	0.0	<.005	<.005	<.005	<.005
Metolachlor	24	100	0.0	.77	.22	.050	7.6
Metolachlor ESA	22	100	--	5.2	4.7	1.6	12
Metolachlor OA	22	95.4	--	1.3	1.1	<.20	3.2
Metribuzin	23	14.3	0.0	.004	<.004	<.004	.029
Molinate	24	0.0	--	<.004	<.004	<.004	<.004
Napropamide	24	0.0	--	<.003	<.003	<.003	<.003
p,p'-DDE	24	0.0	0.0	<.006	<.006	<.006	<.006

Appendix 2. Statistical summary of pesticides and pesticide degradates at the basic-fixed sampling sites in the Eastern Iowa Basins, 1996–98—Continued

[<, less than indicated detection level; MCL, U.S. Environmental Protection Agency maximum contaminant level; --, MCL not established; * includes estimated concentrations less than the method reporting limit]

Constituent	Number of samples	Detection rate, in percent	Percentage of samples exceeding MCL	Concentration, in micrograms per liter			
				Mean	Median	Minimum	Maximum
Parathion	24	0.0	--	<.004	<.004	<.004	<.004
Wapsipinicon River near Tripoli, Iowa (site 1; fig. 1, table 2)—Continued							
Parathion-methyl	24	0.0	0.0	<.006	<.006	<.006	<.006
Pebulate	24	0.0	--	<.004	<.004	<.004	<.004
Pendimethalin	24	9.1	--	<.004	<.004	<.004	.038
Phorate	24	0.0	--	<.002	<.002	<.002	<.002
*Prometon	24	81.8	0.0	.012	<.009	<.009	.058
Propachlor	24	0.0	0.0	<.007	<.007	<.007	<.007
Propanil	24	0.0	--	<.004	<.004	<.004	<.004
Propargite	24	0.0	--	<.013	<.013	<.013	<.013
Propyzamide	24	4.5	0.0	.004	<.003	<.003	.064
Simazine	24	40.9	0.0	.006	<.005	<.005	.032
Tebuthiuron	24	22.7	0.0	<.010	<.010	<.010	.016
Terbacil	24	0.0	0.0	<.007	<.007	<.007	<.007
Terbufos	24	0.0	0.0	<.013	<.013	<.013	<.013
Thiobencarb	24	0.0	--	<.002	<.002	<.002	<.002
Triallate	24	0.0	--	<.001	<.001	<.001	<.001
Trifluralin	24	4.5	0.0	<.002	<.002	<.002	.005
Wapsipinicon River near DeWitt, Iowa (site 2, fig. 1, table 2)							
2,6-Diethylaniline	22	0.0	--	<.003	<.003	<.003	<.003
Acetochlor	22	86.4	0.0	.422	.031	<.002	2.3
Acetochlor ESA	22	72.7	--	1.3	.98	<.20	3.9
Acetochlor OA	21	47.6	--	.88	<.20	<.20	4.9
Alachlor	22	86.4	0.0	.035	.016	<.002	.14
Alachlor ESA	22	100	--	2.2	2.3	.62	3.6
Alachlor OA	21	23.8	--	.23	<.20	<.20	.46
alpha-HCH	22	0.0	0.0	<.002	<.002	<.002	<.002
Atrazine	22	100	22.7	1.7	.19	.11	8.2
Azinphos-methyl	22	0.0	0.0	<.001	<.001	<.001	<.001
Benfluralin	22	0.0	--	<.002	<.002	<.002	<.002
Butylate	22	0.0	0.0	<.002	<.002	<.002	<.002
Carbaryl	22	0.0	0.0	<.003	<.003	<.003	<.003
Carbofuran	22	22.7	0.0	.063	<.003	<.003	.47
Chlorpyrifos	22	9.1	0.0	<.004	<.004	<.004	.029
cis-Permethrin	22	0.0	--	<.005	<.005	<.005	<.005
Cyanazine	22	90.9	0.0	.178	.020	<.004	.96
Cyanazine-amide	20	35	--	.20	<.05	<.05	.79
Dacthal	22	4.5	--	<.002	<.002	<.002	<.002
Deethylatrazine	21	100	--	.34	.26	.11	.88
Deisopropylatrazine	21	66.7	--	.14	.08	<.05	.53
Diazinon	22	0.0	0.0	<.002	<.002	<.002	<.002

Appendix 2. Statistical summary of pesticides and pesticide degradates at the basic-fixed sampling sites in the Eastern Iowa Basins, 1996–98—Continued

[<, less than indicated detection level; MCL, U.S. Environmental Protection Agency maximum contaminant level; --, MCL not established; * includes estimated concentrations less than the method reporting limit]

Constituent	Number of samples	Detection rate, in percent	Percentage of samples exceeding MCL	Concentration, in micrograms per liter			
				Mean	Median	Minimum	Maximum
Dieldrin	22	0.0	0.0	<.001	<.001	<.001	<.001
Wapsipinicon River near DeWitt, Iowa (site 2, fig. 1, table 2)—Continued							
Disulfoton	22	0.0	0.0	<.017	<.017	<.017	<.017
EPTC	22	18.2	--	.004	<.002	<.002	.064
Ethalfuralin	22	0.0	--	<.004	<.004	<.004	<.004
Ethoprophos	22	0.0	--	<.003	<.003	<.003	<.003
Fonofos	22	9.1	0.0	<.003	<.003	<.003	.016
Hydroxy atrazine	21	66.7	--	.37	.30	<.20	.92
Lindane	22	0.0	0.0	<.004	<.004	<.004	<.004
Linuron	22	0.0	--	<.002	<.002	<.002	<.002
Malathion	22	0.0	0.0	<.005	<.005	<.005	<.005
Metolachlor	22	100	0.0	1.02	.297	.028	6.0
Metolachlor ESA	22	100	--	4.0	4.3	1.9	6.1
Metolachlor OA	21	95.2	--	1.1	.80	<.20	3.5
Metribuzin	22	9.1	0.0	<.004	<.004	<.004	0.02
Molinate	22	0.0	--	<.004	<.004	<.004	<.004
Napropamide	22	0.0	--	<.003	<.003	<.003	<.003
p,p'-DDE	22	0.0	0.0	<.006	<.006	<.006	<.006
Parathion	22	0.0	--	<.004	<.004	<.004	<.004
Parathion-methyl	22	0.0	0.0	<.006	<.006	<.006	<.006
Pebulate	22	0.0	--	<.004	<.004	<.004	<.004
Pendimethalin	22	0.0	--	<.004	<.004	<.004	<.004
Phorate	22	0.0	--	<.002	<.002	<.002	<.002
*Prometon	22	81.8	0.0	.009	.009	<.009	.015
Propachlor	22	9.1	0.0	<.007	<.007	<.007	.015
Propanil	22	0.0	--	<.004	<.004	<.004	<.004
Propargite	22	0.0	--	<.013	<.013	<.013	<.013
Propyzamide	22	0.0	0.0	<.003	<.003	<.003	<.003
Simazine	22	40.9	0.0	.008	<.005	<.005	.027
Tebuthiuron	22	22.7	0.0	<.010	<.010	<.010	.021
Terbacil	22	0.0	0.0	<.007	<.007	<.007	<.007
Terbufos	22	0.0	0.0	<.013	<.013	<.013	<.013
Thiobencarb	22	0.0	--	<.002	<.002	<.002	<.002
Triallate	22	0.0	--	<.001	<.001	<.001	<.001
Trifluralin	22	4.5	0.0	<.002	<.002	<.002	<.002
Iowa River near Rowan, Iowa (site 3, fig. 1, table 2)							
2,6-Diethylaniline	52	5.9	--	<.003	<.003	<.003	<.003
Acetochlor	52	84.3	0.0	.074	.014	<.002	.921
Acetochlor ESA	50	70	--	.43	.28	<.20	1.5
Acetochlor OA	50	24	--	.29	<.20	<.20	1.3
Alachlor	52	78.4	0.0	.023	.006	<.002	.559
Alachlor ESA	50	100	--	1.5	1.4	.46	2.8

Appendix 2. Statistical summary of pesticides and pesticide degradates at the basic-fixed sampling sites in the Eastern Iowa Basins, 1996–98—Continued

[<, less than indicated detection level; MCL, U.S. Environmental Protection Agency maximum contaminant level; --, MCL not established; * includes estimated concentrations less than the method reporting limit]

Constituent	Number of samples	Detection rate, in percent	Percentage of samples exceeding MCL	Concentration, in micrograms per liter			
				Mean	Median	Minimum	Maximum
Alachlor OA	50	14	--	.22	<.20	<.20	.67
Iowa River near Rowan, Iowa(site 3, fig. 1, table 2)—Continued							
alpha-HCH	52	0.0	0.0	<.002	<.002	<.002	<.002
Atrazine	52	100	5.9	.426	.069	.023	6.7
Azinphos-methyl	52	0.0	0.0	<.001	<.001	<.001	<.001
Benfluralin	52	0.0	--	<.002	<.002	<.002	<.002
Butylate	52	0.0	0.0	<.002	<.002	<.002	<.002
Carbaryl	52	0.0	0.0	<.003	<.003	<.003	<.003
Carbofuran	52	9.8	0.0	.010	<.003	<.003	.30
Chlorpyrifos	52	2.0	0.0	<.004	<.004	<.004	<.004
cis-Permethrin	52	0.0	--	<.005	<.005	<.005	<.005
Cyanazine	52	41.2	0.0	.015	<.004	<.004	.26
Cyanazine-amide	49	8.1	--	.05	<.05	<.05	.17
Dacthal	52	3.9	--	<.002	<.002	<.002	.007
Deethylatrazine	47	68.1	--	.106	.07	.025	.82
Deisopropylatrazine	47	38.3	--	.05	<.05	<.05	.39
Diazinon	52	2.0	0.0	<.002	<.002	<.002	.004
Dieldrin	52	2.0	0.0	<.001	<.001	<.001	.011
Disulfoton	52	0.0	0.0	<.017	<.017	<.017	<.017
EPTC	52	13.7	--	<.002	<.002	<.002	.049
Ethalfuralin	52	0.0	--	<.004	<.004	<.004	<.004
Ethoprophos	52	0.0	--	<.003	<.003	<.003	<.003
Fonofos	52	0.0	0.0	<.003	<.003	<.003	<.003
Hydroxyatrazine	50	34	--	.31	<.20	<.20	1.7
Lindane	52	0.0	0.0	<.004	<.004	<.004	<.004
Linuron	52	0.0	--	<.002	<.002	<.002	<.002
Malathion	52	0.0	0.0	<.005	<.005	<.005	<.005
Metolachlor	52	100	0.0	.76	.20	.036	11.6
Metolachlor ESA	50	100	--	5.0	5.0	2.2	10
Metolachlor OA	50	100	--	1.0	.91	.41	3.0
Metribuzin	52	17.6	0.0	<.004	<.004	<.004	.026
Molinate	52	0.0	--	<.004	<.004	<.004	<.004
Napropamide	52	0.0	--	<.003	<.003	<.003	<.003
p,p'-DDE	52	0.0	0.0	<.006	<.006	<.006	<.006
Parathion	52	0.0	--	<.004	<.004	<.004	<.004
Parathion-methyl	52	0.0	0.0	<.006	<.006	<.006	<.006
Pebulate	52	0.0	--	<.004	<.004	<.004	<.004
Pendimethalin	52	2.0	--	<.004	<.004	<.004	.103
Phorate	52	0.0	--	<.002	<.002	<.002	<.002
*Prometon	52	98.0	0.0	.013	.010	<.009	.063
Propachlor	52	3.9	0.0	<.007	<.007	<.007	.007
Propanil	52	0.0	--	<.004	<.004	<.004	<.004

Appendix 2. Statistical summary of pesticides and pesticide degradates at the basic-fixed sampling sites in the Eastern Iowa Basins, 1996–98—Continued

[<, less than indicated detection level; MCL, U.S. Environmental Protection Agency maximum contaminant level; --, MCL not established; * includes estimated concentrations less than the method reporting limit]

Constituent	Number of samples	Detection rate, in percent	Percentage of samples exceeding MCL	Concentration, in micrograms per liter			
				Mean	Median	Minimum	Maximum
Propargite	52	0.0	--	<.013	<.013	<.013	<.013
Iowa River near Rowan, Iowa (site 3, fig. 1, table 2)—Continued							
Propyzamide	52	0.0	0.0	<.003	<.003	<.003	<.003
Simazine	52	15.7	0.0	<.005	<.005	<.005	.016
Tebuthiuron	52	0.0	0.0	<.010	<.010	<.010	<.010
Terbacil	52	0.0	0.0	<.007	<.007	<.007	<.007
Terbufos	52	0.0	0.0	<.013	<.013	<.013	<.013
Thiobencarb	52	0.0	--	<.002	<.002	<.002	<.002
Triallate	52	0.0	--	<.001	<.001	<.001	<.001
Trifluralin	52	31.4	0.0	<.002	<.002	<.002	.038
South Fork Iowa River near New Providence, Iowa (site 4, fig. 1, table 2)							
2,6-Diethylaniline	22	4.5	--	.001	<.003	.001	<.003
Acetochlor	22	86.4	0.0	.133	.036	<.002	.915
Acetochlor ESA	21	66.7	--	.70	.35	<.20	1.9
Acetochlor OA	21	38.1	--	.47	<.20	<.20	2.6
Alachlor	22	72.7	0.0	.021	.007	<.002	.28
Alachlor ESA	21	100	--	.78	.77	.22	1.3
Alachlor OA	21	4.7	--	.20	<.20	<.20	.27
alpha-HCH	22	0.0	0.0	<.002	<.002	<.002	<.002
Atrazine	22	100	9.1	1.92	.186	.072	20
Azinphos-methyl	22	0.0	0.0	<.001	<.001	<.001	<.001
Benfluralin	22	0.0	--	<.002	<.002	<.002	<.002
Butylate	22	0.0	0.0	<.002	<.002	<.002	<.002
Carbaryl	22	0.0	0.0	<.003	<.003	<.003	<.003
Carbofuran	22	18.2	0.0	.084	<.003	<.003	1.5
Chlorpyrifos	22	4.5	0.0	<.004	<.004	<.004	.013
cis-Permethrin	22	0.0	--	<.005	<.005	<.005	<.005
Cyanazine	22	59.1	0.0	.014	0.005	<.004	0.10
Cyanazine-amide	20	5	--	.05	<.05	<.05	.09
Dacthal	22	4.5	--	<.002	<.002	<.002	.003
Deethylatrazine	19	100	--	.228	0.140	0.06	.99
Deisopropylatrazine	19	31.6	--	.08	<.05	<.05	.41
Diazinon	22	0.0	0.0	<.002	<.002	<.002	<.002
Dieldrin	22	0.0	0.0	<.001	<.001	<.001	<.001
Disulfoton	22	0.0	0.0	<.017	<.017	<.017	<.017
EPTC	22	18.2	--	.002	<.002	<.002	.016
Ethalfuralin	22	0.0	--	<.004	<.004	<.004	<.004
Ethoprophos	22	0.0	--	<.003	<.003	<.003	<.003
Fonofos	22	0.0	0.0	<.003	<.003	<.003	<.003
Hydroxyatrazine	21	19	--	.29	<.20	<.20	1.3
Lindane	22	0.0	0.0	<.004	<.004	<.004	<.004
Linuron	22	0.0	--	<.002	<.002	<.002	<.002

Appendix 2. Statistical summary of pesticides and pesticide degradates at the basic-fixed sampling sites in the Eastern Iowa Basins, 1996–98—Continued

[<, less than indicated detection level; MCL, U.S. Environmental Protection Agency maximum contaminant level; --, MCL not established; * includes estimated concentrations less than the method reporting limit]

Constituent	Number of samples	Detection rate, in percent	Percentage of samples exceeding MCL	Concentration, in micrograms per liter			
				Mean	Median	Minimum	Maximum
Malathion	22	0.0	0.0	<.005	<.005	<.005	<.005
South Fork Iowa River near New Providence, Iowa (site 4, fig. 1, table 2)—Continued							
Metolachlor	22	100	0.0	1.4	0.50	.079	11
Metolachlor ESA	21	100	--	5.3	5.1	1.8	9.5
Metolachlor OA	21	100	--	1.3	.96	.31	5.3
Metribuzin	22	13.6	0.0	.004	<.004	<.004	.019
Molinate	22	0.0	--	<.004	<.004	<.004	<.004
Napropamide	22	0.0	--	<.003	<.003	<.003	<.003
p,p'-DDE	22	0.0	0.0	<.006	<.006	<.006	<.006
Parathion	22	0.0	--	<.004	<.004	<.004	<.004
Parathion-methyl	22	0.0	0.0	<.006	<.006	<.006	<.006
Pebulate	22	0.0	--	<.004	<.004	<.004	<.004
Pendimethalin	22	9.1	--	.004	<.004	<.004	.038
Phorate	22	0.0	--	<.002	<.002	<.002	<.002
*Prometon	22	77.3	0.0	.016	<.009	<.009	.099
Propachlor	22	0.0	0.0	<.007	<.007	<.007	<.007
Propanil	22	0.0	--	<.004	<.004	<.004	<.004
Propargite	22	0.0	--	<.013	<.013	<.013	<.013
Propyzamide	22	0.0	0.0	<.003	<.003	<.003	<.003
Simazine	22	50.0	0.0	.052	<.005	<.005	.691
Tebuthiuron	22	13.6	0.0	<.010	<.010	<.010	<.010
Terbacil	22	0.0	0.0	<.007	<.007	<.007	<.007
Terbufos	22	0.0	0.0	<.013	<.013	<.013	<.013
Thiobencarb	22	0.0	--	<.002	<.002	<.002	<.002
Triallate	22	0.0	--	<.001	<.001	<.001	<.001
Trifluralin	22	22.7	0.0	.002	<.002	<.002	.015
Iowa River at Marengo, Iowa (site 5, fig. 1, table 2)							
2,6-Diethylaniline	23	0.0	--	<.003	<.003	<.003	<.003
Acetochlor	23	87.0	0.0	.190	.036	<.002	1.5
Acetochlor ESA	23	69.6	--	.56	.41	.14	1.6
Acetochlor OA	23	39.1	--	.39	<.20	<.20	1.4
Alachlor	23	73.9	0.0	.013	.005	<.002	.053
Alachlor ESA	23	100	--	.97	.31	.31	1.9
Alachlor OA	23	26.1	--	.21	<.20	<.20	.32
alpha-HCH	23	0.0	0.0	<.002	<.002	<.002	<.002
Atrazine	23	100	13.0	1.05	.156	.073	7.61
Azinphos-methyl	23	0.0	0.0	<.001	<.001	<.001	<.001
Benfluralin	23	0.0	--	<.002	<.002	<.002	<.002
Butylate	23	0.0	0.0	<.002	<.002	<.002	<.002
Carbaryl	23	0.0	0.0	<.003	<.003	<.003	<.003
Carbofuran	23	13.0	0.0	.027	<.003	<.003	0.445
Chlorpyrifos	23	8.7	0.0	.004	<.004	<.004	.029

Appendix 2. Statistical summary of pesticides and pesticide degradates at the basic-fixed sampling sites in the Eastern Iowa Basins, 1996–98—Continued

[<, less than indicated detection level; MCL, U.S. Environmental Protection Agency maximum contaminant level; --, MCL not established; * includes estimated concentrations less than the method reporting limit]

Constituent	Number of samples	Detection rate, in percent	Percentage of samples exceeding MCL	Concentration, in micrograms per liter			
				Mean	Median	Minimum	Maximum
cis-Permethrin	23	0.0	--	<.005	<.005	<.005	<.005
Iowa River at Marengo, Iowa (site 5, fig. 1, table 2)—Continued							
Cyanazine	23	95.7	4.3	.350	0.024	<.004	6.3
Cyanazine-amide	21	42.8	--	.15	<.05	<.05	.97
Dacthal	23	0.0	--	<.002	<.002	<.002	<.002
Deethylatrazine	21	100	--	.211	.13	.05	.88
Deisopropylatrazine	21	66.7	--	.10	.07	<.05	.41
Diazinon	23	0.0	0.0	<.002	<.002	<.002	<.002
Dieldrin	23	0.0	0.0	<.001	<.001	<.001	<.001
Disulfoton	23	0.0	0.0	<.017	<.017	<.017	<.017
EPTC	23	8.7	--	<.002	<.002	<.002	.007
Ethalfuralin	23	0.0	--	<.004	<.004	<.004	<.004
Ethoprophos	23	0.0	--	<.003	<.003	<.003	<.003
Fonofos	23	8.7	0.0	<.003	<.003	<.003	.016
Hydroxy atrazine	23	39.1	--	.33	<.20	<.20	1.2
Lindane	23	0.0	0.0	<.004	<.004	<.004	<.004
Linuron	23	0.0	--	<.002	<.002	<.002	<.002
Malathion	23	0.0	0.0	<.005	<.005	<.005	<.005
Metolachlor	23	100	0.0	.847	.358	.046	3.59
Metolachlor ESA	23	100	--	3.7	3.8	2.0	5.6
Metolachlor OA	23		--	.83	.69	<.20	1.9
Metribuzin	23	26.1	0.0	.006	<.004	<.004	.036
Molinate	23	0.0	--	<.004	<.004	<.004	<.004
Napropamide	23	0.0	--	<.003	<.003	<.003	<.003
p,p'-DDE	23	0.0	0.0	<.006	<.006	<.006	<.006
Parathion	23	0.0	--	<.004	<.004	<.004	<.004
Parathion-methyl	23	0.0	0.0	<.006	<.006	<.006	<.006
Pebulate	23	0.0	--	<.004	<.004	<.004	<.004
Pendimethalin	23	8.7	--	.005	<.004	<.004	.039
Phorate	23	0.0	--	<.002	<.002	<.002	<.002
*Prometon	23	87.0	0.0	.013	.010	<.009	.044
Propachlor	23	4.3	0.0	<.007	<.007	<.007	.007
Propanil	23	0.0	--	<.004	<.004	<.004	<.004
Propargite	23	0.0	--	<.013	<.013	<.013	<.013
Propyzamide	23	0.0	0.0	<.003	<.003	<.003	<.003
Simazine	23	47.8	0.0	.009	<.005	<.005	.054
Tebuthiuron	23	0.0	0.0	<.010	<.010	<.010	<.010
Terbacil	23	0.0	0.0	<.007	<.007	<.007	<.007
Terbufos	23	0.0	0.0	<.013	<.013	<.013	<.013
Thiobencarb	23	0.0	--	<.002	<.002	<.002	<.002
Triallate	23	0.0	--	<.001	<.001	<.001	<.001

Appendix 2. Statistical summary of pesticides and pesticide degradates at the basic-fixed sampling sites in the Eastern Iowa Basins, 1996–98—Continued

[<, less than indicated detection level; MCL, U.S. Environmental Protection Agency maximum contaminant level; --, MCL not established; * includes estimated concentrations less than the method reporting limit]

Constituent	Number of samples	Detection rate, in percent	Percentage of samples exceeding MCL	Concentration, in micrograms per liter			
				Mean	Median	Minimum	Maximum
Trifluralin	23	13.0	0.0	<.002	<.002	<.002	.008
Old Mans Creek nr Iowa City, Iowa (site 6, fig. 1, table 2)							
2,6-Diethylaniline	26	3.8	--	<.003	<.003	<.003	.003
Acetochlor	26	88.5	0.0	.549	.028	<.002	5.7
Acetochlor ESA	26	80.8	--	.77	.54	<.20	2.0
Acetochlor OA	26	46.2	--	.47	<.20	<.20	2.1
Alachlor	26	57.7	0.0	.021	.005	<.002	.296
Alachlor ESA	26	96.2	--	1.1	1.1	<.20	1.9
Alachlor OA	26	23.1	--	.23	<.20	<.20	.51
alpha-HCH	26	0.0	0.0	<.002	<.002	<.002	<.002
Atrazine	26	100	19.2	1.9	0.37	.078	20
Azinphos-methyl	26	0.0	0.0	<.001	<.001	<.001	<.001
Benfluralin	26	0.0	--	<.002	<.002	<.002	<.002
Butylate	26	7.7	0.0	.002	<.002	<.002	.018
Carbaryl	26	3.8	0.0	.004	<.003	<.003	.057
Carbofuran	26	15.4	0.0	.008	<.003	<.003	.064
Chlorpyrifos	26	26.9	0.0	.007	<.004	<.004	.033
cis-Permethrin	26	0.0	--	<.005	<.005	<.005	<.005
Cyanazine	26	96.2	11.5	.91	.102	<.004	9.9
Cyanazine-amide	25	68.0	--	.32	.14	<.05	2.8
Dacthal	26	3.8	--	<.002	<.002	<.002	.002
Deethylatrazine	25	92.0	--	.223	.16	<.05	.76
Deisopropylatrazine	25	80	--	.15	.13	<.05	.53
Diazinon	26	0.0	0.0	<.002	<.002	<.002	<.002
Dieldrin	26	0.0	0.0	<.001	<.001	<.001	<.001
Disulfoton	26	0.0	0.0	<.017	<.017	<.017	<.017
EPTC	26	26.9	--	.004	<.002	<.002	.026
Ethalfuralin	26	0.0	--	<.004	<.004	<.004	<.004
Ethoprophos	26	0.0	--	<.003	<.003	<.003	<.003
Fonofos	26	26.9	0.0	.026	<.003	<.003	.42
Hydroxyatrazine	26	69.2	--	.43	.30	<.20	1.2
Lindane	26	3.8	0.0	<.004	<.004	<.004	.018
Linuron	26	0.0	--	<.002	<.002	<.002	<.002
Malathion	26	3.8	0.0	.005	<.005	<.005	.078
Metolachlor	26	100	0.0	.972	.114	.031	10
Metolachlor ESA	26	100	--	1.9	1.7	.77	3.2
Metolachlor OA	26	88.5	--	.57	.49	<.20	1.4
Metribuzin	26	19.2	0.0	.015	<.004	<.004	.15
Molinate	26	0.0	--	<.004	<.004	<.004	<.004
Napropamide	26	0.0	--	<.003	<.003	<.003	<.003
p,p'-DDE	26	0.0	0.0	<.006	<.006	<.006	<.006
Parathion	26	0.0	--	<.004	<.004	<.004	<.004

Appendix 2. Statistical summary of pesticides and pesticide degradates at the basic-fixed sampling sites in the Eastern Iowa Basins, 1996–98—Continued

[<, less than indicated detection level; MCL, U.S. Environmental Protection Agency maximum contaminant level; --, MCL not established; * includes estimated concentrations less than the method reporting limit]

Constituent	Number of samples	Detection rate, in percent	Percentage of samples exceeding MCL	Concentration, in micrograms per liter			
				Mean	Median	Minimum	Maximum
Parathion-methyl	26	0.0	0.0	<.006	<.006	<.006	<.006
Old Mans Creek nr Iowa City, Iowa (site 6, fig. 1, table 2)—Continued							
Pebulate	26	0.0	--	<.004	<.004	<.004	<.004
Pendimethalin	26	3.8	--	.002	<.004	<.004	.006
Phorate	26	0.0	--	<.002	<.002	<.002	<.002
*Prometon	26	26.9	0.0	<.009	<.009	<.009	.019
Propachlor	26	3.8	0.0	<.007	<.007	<.007	.004
Propanil	26	0.0	--	<.004	<.004	<.004	<.004
Propargite	26	0.0	--	<.013	<.013	<.013	<.013
Propyzamide	26	0.0	0.0	<.003	<.003	<.003	<.003
Simazine	26	19.2	0.0	.009	<.005	<.005	.088
Tebuthiuron	26	0.0	0.0	<.010	<.010	<.010	<.010
Terbacil	26	0.0	0.0	<.007	<.007	<.007	<.007
Terbufos	26	0.0	0.0	<.013	<.013	<.013	<.013
Thiobencarb	26	0.0	--	<.002	<.002	<.002	<.002
Triallate	26	0.0	--	<.001	<.001	<.001	<.001
Trifluralin	26	23.1	0.0	.004	<.002	<.002	.007
Flood Creek near Powersville, Iowa (site 7, fig. 1, table 2)							
2,6-Diethylaniline	21	0.0	--	<.003	<.003	<.003	<.003
Acetochlor	21	57.1	0.0	.162	.005	<.002	2.56
Acetochlor ESA	18	55.6	--	.86	.40	<.20	2.1
Acetochlor OA	17	23.5	--	.45	<.20	<.20	1.7
Alachlor	21	38.1	0.0	.017	<.002	<.002	0.14
Alachlor ESA	18	100	--	1.9	1.7	.91	3.3
Alachlor OA	17	5.9	--	.22	<.20	<.20	.45
alpha-HCH	21	0.0	0.0	<.002	<.002	<.002	<.002
Atrazine	21	100	0.0	.350	.152	.037	2.0
Azinphos-methyl	21	0.0	0.0	<.001	<.001	<.001	<.001
Benfluralin	21	0.0	--	<.002	<.002	<.002	<.002
Butylate	21	4.8	0.0	<.002	<.002	<.002	.002
Carbaryl	21	0.0	0.0	<.003	<.003	<.003	<.003
Carbofuran	21	14.3	0.0	.025	<.003	<.003	.440
Chlorpyrifos	21	4.8	0.0	<.004	<.004	<.004	.004
cis-Permethrin	21	0.0	--	<.005	<.005	<.005	<.005
Cyanazine	21	42.9	0.0	.016	<.004	<.004	.11
Cyanazine-amide	18	22.2	--	.06	<.05	<.05	.19
Dacthal	21	9.5	--	<.002	<.002	<.002	.002
Deethylatrazine	16	100	--	.209	.155	.07	.53
Deisopropylatrazine	16	37.5	--	.05	<.05	<.05	.17
Diazinon	21	0.0	0.0	<.002	<.002	<.002	<.002
Dieldrin	21	0.0	0.0	<.001	<.001	<.001	<.001
Disulfoton	21	0.0	0.0	<.017	<.017	<.017	<.017

Appendix 2. Statistical summary of pesticides and pesticide degradates at the basic-fixed sampling sites in the Eastern Iowa Basins, 1996–98—Continued

[<, less than indicated detection level; MCL, U.S. Environmental Protection Agency maximum contaminant level; --, MCL not established; * includes estimated concentrations less than the method reporting limit]

Constituent	Number of samples	Detection rate, in percent	Percentage of samples exceeding MCL	Concentration, in micrograms per liter			
				Mean	Median	Minimum	Maximum
EPTC	21	19.0	--	<.002	<.002	<.002	.007
Flood Creek near Powersville, Iowa (site 7, fig. 1, table 2)—Continued							
Ethalfuralin	21	0.0	--	<.004	<.004	<.004	<.004
Ethoprophos	21	0.0	--	<.003	<.003	<.003	<.003
Fonofos	21	0.0	0.0	<.003	<.003	<.003	<.003
Hydroxyatrazine	17	5.9	--	.24	<.20	<.20	.90
Lindane	21	0.0	0.0	<.004	<.004	<.004	<.004
Linuron	21	0.0	--	<.002	<.002	<.002	<.002
Malathion	21	0.0	0.0	<.005	<.005	<.005	<.005
Metolachlor	21	100	0.0	.618	.096	.004	3.56
Metolachlor ESA	18	100	--	6.1	4.7	1.7	12
Metolachlor OA	17	58.8	--	1.1	.35	<.20	3.3
Metribuzin	20	10.0	0.0	<.004	<.004	<.004	.007
Molinate	21	0.0	--	<.004	<.004	<.004	<.004
Napropamide	21	0.0	--	<.003	<.003	<.003	<.003
p,p'-DDE	21	4.8	0.0	<.006	<.006	<.006	.006
Parathion	21	0.0	--	<.004	<.004	<.004	<.004
Parathion-methyl	21	0.0	0.0	<.006	<.006	<.006	<.006
Pebulate	21	0.0	--	<.004	<.004	<.004	<.004
Pendimethalin	21	0.0	--	<.004	<.004	<.004	<.004
Phorate	21	0.0	--	<.002	<.002	<.002	<.002
*Prometon	21	57.1	0.0	<.009	<.009	<.009	.010
Propachlor	21	0.0	0.0	<.007	<.007	<.007	<.007
Propanil	21	0.0	--	<.004	<.004	<.004	<.004
Propargite	21	0.0	--	<.013	<.013	<.013	<.013
Propyzamide	21	0.0	0.0	<.003	<.003	<.003	<.003
Simazine	21	23.8	0.0	<.005	<.005	<.005	.017
Tebuthiuron	21	0.0	0.0	<.010	<.010	<.010	<.010
Terbacil	21	0.0	0.0	<.007	<.007	<.007	<.007
Terbufos	21	0.0	0.0	<.013	<.013	<.013	<.013
Thiobencarb	21	0.0	--	<.002	<.002	<.002	<.002
Triallate	21	0.0	--	<.001	<.001	<.001	<.001
Trifluralin	21	23.8	0.0	.002	<.002	<.002	.010
Cedar River at Gilbertville, Iowa (site 8, fig. 1, table 2)							
2,6-Diethylaniline	12	0.0	--	<.003	<.003	<.003	<.003
Acetochlor	12	66.7	0.0	.160	.012	<.002	1.66
Acetochlor ESA	11	27.3	--	.38	<.20	<.20	1.7
Acetochlor OA	11	18.2	--	.30	<.20	<.20	1.3
Alachlor	12	50.0	0.0	.006	.002	<.002	.03
Alachlor ESA	11	90.9	--	1.8	2.0	<.20	2.6
Alachlor OA	11	27.3	--	.22	<.20	<.20	.32
alpha-HCH	12	0.0	0.0	<.002	<.002	<.002	<.002

Appendix 2. Statistical summary of pesticides and pesticide degradates at the basic-fixed sampling sites in the Eastern Iowa Basins, 1996–98—Continued

[<, less than indicated detection level; MCL, U.S. Environmental Protection Agency maximum contaminant level; --, MCL not established; * includes estimated concentrations less than the method reporting limit]

Constituent	Number of samples	Detection rate, in percent	Percentage of samples exceeding MCL	Concentration, in micrograms per liter			
				Mean	Median	Minimum	Maximum
Atrazine	12	100	0.0	.232	.096	.061	1.5
Cedar River at Gilbertville, Iowa (site 8, fig. 1, table 2—Continued)							
Azinphos-methyl	12	0.0	0.0	<.001	<.001	<.001	<.001
Benfluralin	12	0.0	--	<.002	<.002	<.002	<.002
Butylate	12	0.0	0.0	<.002	<.002	<.002	<.002
Carbaryl	12	0.0	0.0	<.003	<.003	<.003	<.003
Carbofuran	12	8.3	0.0	.018	<.003	<.003	.20
Chlorpyrifos	12	8.3	0.0	<.004	<.004	<.004	.009
cis-Permethrin	12	0.0	--	<.005	<.005	<.005	<.005
Cyanazine	12	66.7	0.0	.029	.007	<.004	.21
Cyanazine-amide	11	27.3	--	.07	<.05	<.05	.14
Dacthal	12	8.3	--	<.002	<.002	<.002	.002
Deethylatrazine	12	100	--	0.14	.13	.07	.35
Deisopropylatrazine	12	66.7	--	.06	.05	<.05	.14
Diazinon	12	16.7	0.0	.002	<.002	<.002	.008
Dieldrin	12	0.0	0.0	<.001	<.001	<.001	<.001
Disulfoton	12	0.0	0.0	<.017	<.017	<.017	<.017
EPTC	12	16.7	--	<.002	<.002	<.002	.007
Ethalfuralin	12	0.0	--	<.004	<.004	<.004	<.004
Ethoprophos	12	0.0	--	<.003	<.003	<.003	<.003
Fonofos	12	0.0	0.0	<.003	<.003	<.003	<.003
Hydroxyatrazine	11	27.3	--	.23	<.20	<.20	.38
Lindane	12	0.0	0.0	<.004	<.004	<.004	<.004
Linuron	12	0.0	--	<.002	<.002	<.002	<.002
Malathion	12	0.0	0.0	<.005	<.005	<.005	<.005
Metolachlor	12	100	0.0	.278	.176	.035	1.0
Metolachlor ESA	11	90.9	--	3.2	3.4	<.20	5.4
Metolachlor OA	11	81.8	--	.62	.51	<.20	1.5
Metribuzin	12	8.3	0.0	<.004	<.004	<.004	0.018
Molinate	12	0.0	--	<.004	<.004	<.004	<.004
Napropamide	12	0.0	--	<.003	<.003	<.003	<.003
p,p'-DDE	12	0.0	0.0	<.006	<.006	<.006	<.006
Parathion	12	0.0	--	<.004	<.004	<.004	<.004
Parathion-methyl	12	0.0	0.0	<.006	<.006	<.006	<.006
Pebulate	12	0.0	--	<.004	<.004	<.004	<.004
Pendimethalin	12	0.0	--	<.004	<.004	<.004	<.004
Phorate	12	0.0	--	<.002	<.002	<.002	<.002
*Prometon	12	100	0.0	.013	.011	<.009	.025
Propachlor	12	0.0	0.0	<.007	<.007	<.007	<.007
Propanil	12	0.0	--	<.004	<.004	<.004	<.004
Propargite	12	0.0	--	<.013	<.013	<.013	<.013
Propyzamide	12	0.0	0.0	<.003	<.003	<.003	<.003

Appendix 2. Statistical summary of pesticides and pesticide degradates at the basic-fixed sampling sites in the Eastern Iowa Basins, 1996–98—Continued

[<, less than indicated detection level; MCL, U.S. Environmental Protection Agency maximum contaminant level; --, MCL not established; * includes estimated concentrations less than the method reporting limit]

Constituent	Number of samples	Detection rate, in percent	Percentage of samples exceeding MCL	Concentration, in micrograms per liter			
				Mean	Median	Minimum	Maximum
Simazine	12	25.0	0.0	<.005	<.005	<.005	.014
Cedar River at Gilbertville, Iowa (site 8, fig. 1, table 2—Continued)							
Tebuthiuron	12	25.0	0.0	<.010	<.010	<.010	.010
Terbacil	12	0.0	0.0	<.007	<.007	<.007	<.007
Terbufos	12	0.0	0.0	<.013	<.013	<.013	<.013
Thiobencarb	12	0.0	--	<.002	<.002	<.002	<.002
Triallate	12	0.0	--	<.001	<.001	<.001	<.001
Trifluralin	12	0.0	0.0	<.002	<.002	<.002	<.002
Wolf Creek near Dysart, Iowa (site 9, fig. 1, table 2)							
2,6-Diethylaniline	53	0.0	--	<.003	<.003	<.003	<.003
Acetochlor	53	73.1	0.0	.117	.011	<.002	1.25
Acetochlor ESA	51	64.7	--	.57	.29	<.20	5.1
Acetochlor OA	51	21.6	--	.46	<.20	<.20	6.8
Alachlor	53	84.6	0.0	.019	.006	<.002	.26
Alachlor ESA	51	98.0	--	1.2	1.2	<.20	2.8
Alachlor OA	51	15.7	--	.21	<.20	<.20	.51
alpha-HCH	53	0.0	0.0	<.002	<.002	<.002	<.002
Atrazine	53	100	11.5	1.18	.18	.048	20
Azinphos-methyl	53	0.0	0.0	<.001	<.001	<.001	<.001
Benfluralin	53	0.0	--	<.002	<.002	<.002	<.002
Butylate	53	0.0	0.0	<.002	<.002	<.002	<.002
Carbaryl	53	0.0	0.0	<.003	<.003	<.003	<.003
Carbofuran	53	13.5	0.0	.031	<.003	<.003	.79
Chlorpyrifos	53	7.7	0.0	<.004	<.004	<.004	.067
cis-Permethrin	53	0.0	--	<.005	<.005	<.005	<.005
Cyanazine	53	94.2	5.8	.139	.028	<.004	1.61
Cyanazine-amide	51	47.1	--	.15	<.05	<.05	1.4
Dacthal	53	1.9	--	<.002	<.002	<.002	.002
Deethylatrazine	46	97.8	--	.208	.140	<.002	.98
Deisopropylatrazine	46	84.8	--	.13	.10	<.05	.52
Diazinon	53	0.0	0.0	<.002	<.002	<.002	<.002
Dieldrin	53	5.8	0.0	<.001	<.001	<.001	.004
Disulfoton	53	0.0	0.0	<.017	<.017	<.017	<.017
EPTC	53	21.2	--	<.002	<.002	<.002	.015
Ethalfuralin	53	0.0	--	<.004	<.004	<.004	<.004
Ethoprophos	53	0.0	--	<.003	<.003	<.003	<.003
Fonofos	53	1.9	0.0	<.003	<.003	<.003	.007
Hydroxyatrazine	51	51.0	--	.33	.20	<.20	1.1
Lindane	53	0.0	0.0	<.004	<.004	<.004	<.004
Linuron	53	0.0	--	<.002	<.002	<.002	<.002
Malathion	53	1.9	0.0	<.005	<.005	<.005	.038
Metolachlor	53	100	0.0	.581	.15	.027	8.72

Appendix 2. Statistical summary of pesticides and pesticide degradates at the basic-fixed sampling sites in the Eastern Iowa Basins, 1996–98—Continued

[<, less than indicated detection level; MCL, U.S. Environmental Protection Agency maximum contaminant level; --, MCL not established; * includes estimated concentrations less than the method reporting limit]

Constituent	Number of samples	Detection rate, in percent	Percentage of samples exceeding MCL	Concentration, in micrograms per liter			
				Mean	Median	Minimum	Maximum
Metolachlor ESA	51	100	--	4.6	4.5	2.3	8.1
Wolf Creek near Dysart, Iowa (site 9, fig. 1, table 2)—Continued							
Metolachlor OA	51	96.1	--	.83	.53	<.20	6.8
Metribuzin	53	15.4	0.0	.012	<.004	<.004	.169
Molinate	53	1.9	--	<.004	<.004	<.004	.023
Napropamide	53	1.9	--	<.003	<.003	<.003	.004
p,p'-DDE	53	0.0	0.0	<.006	<.006	<.006	<.006
Parathion	53	0.0	--	<.004	<.004	<.004	<.004
Parathion-methyl	53	0.0	0.0	<.006	<.006	<.006	<.006
Pebulate	53	0.0	--	<.004	<.004	<.004	<.004
Pendimethalin	53	13.5	--	.008	<.004	<.004	.111
Phorate	53	0.0	--	<.002	<.002	<.002	<.002
*Prometon	53	80.8	0.0	<.009	<.009	<.009	.046
Propachlor	53	1.9	0.0	<.007	<.007	<.007	.006
Propanil	53	0.0	--	<.004	<.004	<.004	<.004
Propargite	53	0.0	--	<.013	<.013	<.013	<.013
Propyzamide	53	0.0	0.0	<.003	<.003	<.003	<.003
Simazine	53	53.8	0.0	<.005	<.005	<.0031	.046
Tebuthiuron	53	3.8	0.0	<.010	<.010	<.010	.006
Terbacil	53	0.0	0.0	<.007	<.007	<.007	<.007
Terbufos	53	0.0	0.0	<.013	<.013	<.013	<.013
Thiobencarb	53	0.0	--	<.002	<.002	<.002	<.002
Triallate	53	0.0	--	<.001	<.001	<.001	<.001
Trifluralin	53	32.7	0.0	<.002	<.002	<.002	.030
Cedar River near Conesville, Iowa¹ (site 10 fig. 1, table 2)							
2,6-Diethylaniline	23	0.0	--	<.003	<.003	<.003	<.003
Acetochlor	23	81.8	0.0	.408	.016	<.002	7.1
Acetochlor ESA	22	72.7	--	.68	.36	<.20	2.7
Acetochlor OA	22	27.2	--	.40	<.20	<.20	2.5
Alachlor	23	68.2	0.0	.020	.005	<.002	.24
Alachlor ESA	22	100	--	1.6	1.5	.73	3.2
Alachlor OA	22	0.0	--	<.20	<.20	<.20	<.20
alpha-HCH	23	0.0	0.0	<.002	<.002	<.002	<.002
Atrazine	23	100	4.5	1.20	.140	.085	20
Azinphos-methyl	23	0.0	0.0	<.001	<.001	<.001	<.001
Benfluralin	23	0.0	--	<.002	<.002	<.002	<.002
Butylate	23	0.0	0.0	<.002	<.002	<.002	<.002
Carbaryl	23	0.0	0.0	<.003	<.003	<.003	<.003
Carbofuran	23	9.1	0.0	<.007	<.003	<.003	.029
Chlorpyrifos	23	0.0	0.0	<.004	<.004	<.004	<.004
cis-Permethrin	23	0.0	--	<.005	<.005	<.005	<.005
Cyanazine	23	81.8	4.5	.300	.012	<.004	6.3

Appendix 2. Statistical summary of pesticides and pesticide degradates at the basic-fixed sampling sites in the Eastern Iowa Basins, 1996–98—Continued

[<, less than indicated detection level; MCL, U.S. Environmental Protection Agency maximum contaminant level; --, MCL not established; * includes estimated concentrations less than the method reporting limit]

Constituent	Number of samples	Detection rate, in percent	Percentage of samples exceeding MCL	Concentration, in micrograms per liter			
				Mean	Median	Minimum	Maximum
Cyanazine-amide	22	32.7	--	.09	<.05	<.05	.55
Cedar River near Conesville, Iowa¹ (site 10 fig. 1, table 2)—Continued							
Dacthal	23	9.1	--	<.002	<.002	<.002	.004
Deethylatrazine	20	100	--	.191	.120	.100	.58
Deisopropylatrazine	20	95.0	--	.10	.08	<.05	.30
Diazinon	23	13.6	0.0	<.002	<.002	<.002	.018
Dieldrin	23	0.0	0.0	<.001	<.001	<.001	.01
Disulfoton	23	0.0	0.0	<.017	<.017	<.017	<.017
EPTC	23	4.5	--	.005	<.002	<.002	.078
Ethalfuralin	23	0.0	--	<.004	<.004	<.004	<.004
Ethoprophos	23	0.0	--	<.003	<.003	<.003	<.003
Fonofos	23	4.5	0.0	.005	<.003	<.003	0.081
Hydroxyatrazine	22	36.4	--	.27	<.20	<.20	.79
Lindane	23	0.0	0.0	<.004	<.004	<.004	<.004
Linuron	23	0.0	--	<.002	<.002	<.002	<.002
Malathion	23	4.5	0.0	<.005	<.005	<.005	0.023
Metolachlor	23	100	0.0	.84	.29	.040	10
Metolachlor ESA	22	100	--	3.5	3.2	1.6	8.5
Metolachlor OA	22	100	--	.76	.62	.33	3.2
Metribuzin	23	9.1	0.0	.004	<.004	<.004	0.052
Molinate	23	0.0	--	<.004	<.004	<.004	<.004
Napropamide	23	0.0	--	<.003	<.003	<.003	<.003
p,p'-DDE	23	0.0	0.0	<.006	<.006	<.006	<.006
Parathion	23	0.0	--	<.004	<.004	<.004	<.004
Parathion-methyl	23	0.0	0.0	<.006	<.006	<.006	<.006
Pebulate	23	0.0	--	<.004	<.004	<.004	<.004
Pendimethalin	23	0.0	--	<.004	<.004	<.004	<.004
Phorate	23	0.0	--	<.002	<.002	<.002	<.002
*Prometon	23	95.5	0.0	.012	.011	<.009	.078
Propachlor	23	4.5	0.0	<.007	<.007	<.007	.007
Propanil	23	0.0	--	<.004	<.004	<.004	<.004
Propargite	23	0.0	--	<.013	<.013	<.013	<.013
Propyzamide	23	0.0	0.0	<.003	<.003	<.003	<.003
Simazine	23	27.3	0.0	.011	<.005	<.005	.16
Tebuthiuron	23	4.5	0.0	<.010	<.010	<.010	.010
Terbacil	23	0.0	0.0	<.007	<.007	<.007	<.007
Terbufos	23	0.0	0.0	<.013	<.013	<.013	<.013
Thiobencarb	23	0.0	--	<.002	<.002	<.002	<.002
Triallate	23	0.0	--	<.001	<.001	<.001	<.001

Appendix 2. Statistical summary of pesticides and pesticide degradates at the basic-fixed sampling sites in the Eastern Iowa Basins, 1996–98—Continued

[<, less than indicated detection level; MCL, U.S. Environmental Protection Agency maximum contaminant level; --, MCL not established; * includes estimated concentrations less than the method reporting limit]

Constituent	Number of samples	Detection rate, in percent	Percentage of samples exceeding MCL	Concentration, in micrograms per liter			
				Mean	Median	Minimum	Maximum
Trifluralin	23	9.1	0.0	<.002	<.002	<.002	.009
Iowa River at Wapello, Iowa (site 11, fig. 1, table 2)							
2,6-Diethylaniline	54	0.0	--	<.003	<.003	<.003	<.003
Acetochlor	54	78.8	0.0	.163	.017	<.002	2.14
Acetochlor ESA	52	90.4	--	.68	.50	<.20	2.6
Acetochlor OA	50	48.0	--	.41	<.20	<.20	2.1
Alachlor	54	73.1	0.0	.018	.006	<.002	.235
Alachlor ESA	52	100	--	1.2	1.1	.58	2.6
Alachlor OA	50	0.0	--	<.20	<.20	<.20	<.20
alpha-HCH	54	0.0	0.0	<.002	<.002	<.002	<.002
Atrazine	54	100	9.6	.858	.160	.073	6.32
Azinphos-methyl	54	0.0	0.0	<.001	<.001	<.001	<.001
Benfluralin	54	0.0	--	<.002	<.002	<.002	<.002
Butylate	54	7.7	0.0	<.002	<.002	<.002	.022
Carbaryl	54	0.0	0.0	<.003	<.003	<.003	<.003
Carbofuran	54	9.6	0.0	.005	<.003	<.003	.094
Chlorpyrifos	54	5.8	0.0	<.004	<.004	<.0029	.048
cis-Permethrin	54	0.0	--	<.005	<.005	<.005	<.005
Cyanazine	54	86.5	3.8	.169	0.022	<.004	2.6
Cyanazine-amide	52	32.7	--	.18	<.05	<.05	1.9
Dacthal	54	7.7	--	<.002	<.002	<.002	.003
Deethylatrazine	49	98.0	--	.224	.150	<.002	.80
Deisopropylatrazine	49	85.7	--	.12	.08	<.05	.46
Diazinon	54	9.6	0.0	.002	<.002	<.002	.057
Dieldrin	54	3.8	0.0	<.001	<.001	<.001	.004
Disulfoton	54	0.0	0.0	<.017	<.017	<.017	<.017
EPTC	54	17.3	--	<.002	<.002	<.002	0.014
Ethalfuralin	54	0.0	--	<.004	<.004	<.004	<.004
Ethoprophos	54	0.0	--	<.003	<.003	<.003	<.003
Fonofos	54	3.8	0.0	<.003	<.003	<.003	.021
Hydroxyatrazine	50	64.0	--	.38	.27	<.20	1.2
Lindane	54	0.0	0.0	<.004	<.004	<.004	<.004
Linuron	54	0.0	--	<.002	<.002	<.002	<.002
Malathion	54	0.0	0.0	<.005	<.005	<.005	<.005
Metolachlor	54	100	0.0	0.65	0.28	0.044	6.1
Metolachlor ESA	52	100	--	3.2	3.0	1.6	7.2
Metolachlor OA	50	100	--	.76	.70	.29	2.5
Metribuzin	54	13.5	0.0	.005	<.004	<.004	.055
Molinate	54	1.9	--	<.004	<.004	<.004	.004
Napropamide	54	0.0	--	<.003	<.003	<.003	<.003
p,p'-DDE	54	1.9	0.0	<.006	<.006	<.006	.006
Parathion	54	0.0	--	<.004	<.004	<.004	<.004
Parathion-methyl	54	0.0	0.0	<.006	<.006	<.006	<.006

Appendix 2. Statistical summary of pesticides and pesticide degradates at the basic-fixed sampling sites in the Eastern Iowa Basins, 1996–98—Continued

[<, less than indicated detection level; MCL, U.S. Environmental Protection Agency maximum contaminant level; --, MCL not established; * includes estimated concentrations less than the method reporting limit]

Constituent	Number of samples	Detection rate, in percent	Percentage of samples exceeding MCL	Concentration, in micrograms per liter			
				Mean	Median	Minimum	Maximum
Pebulate	54	0.0	--	<.004	<.004	<.004	<.004
Iowa River at Wapello, Iowa (site 11, fig. 1, table 2)—Continued							
Pendimethalin	54	7.7	--	.004	<.004	<.004	.085
Phorate	54	0.0	--	<.002	<.002	<.002	<.002
*Prometon	54	94.2	0.0	.011	<.009	<.09	.082
Propachlor	54	3.8	0.0	<.007	<.007	<.007	.007
Propanil	54	0.0	--	<.004	<.004	<.004	<.004
Propargite	54	0.0	--	<.013	<.013	<.013	<.013
Propyzamide	54	0.0	0.0	<.003	<.003	<.003	<.003
Simazine	54	65.4	0.0	.009	.006	<.005	.059
Tebuthiuron	54	0.0	0.0	<.010	<.010	<.010	<.010
Terbacil	54	0.0	0.0	<.007	<.007	<.007	<.007
Terbufos	54	0.0	0.0	<.013	<.013	<.013	<.013
Thiobencarb	54	0.0	--	<.002	<.002	<.002	<.002
Triallate	54	0.0	--	<.001	<.001	<.001	<.001
Trifluralin	54	11.5	0.0	<.002	<.002	<.002	0.007
Skunk River at Augusta, Iowa (site 12, fig. 1, table 2)							
2,6-Diethylaniline	21	0.0	--	<.003	<.003	<.003	<.003
Acetochlor	21	95.2	0.0	.877	.040	<.002	10.6
Acetochlor ESA	20	80.0	--	.72	.56	<.20	2.7
Acetochlor OA	19	47.4	--	.72	<.20	<.20	4.0
Alachlor	21	61.9	0.0	.042	.011	<.002	.53
Alachlor ESA	20	100	--	.53	.48	.21	.96
Alachlor OA	19	15.8	--	.22	<.20	<.20	.50
alpha-HCH	21	0.0	0.0	<.002	<.002	<.002	<.002
Atrazine	21	100	19.0	3.91	0.364	0.108	48.1
Azinphos-methyl	21	0.0	0.0	<.001	<.001	<.001	<.001
Benfluralin	21	0.0	--	<.002	<.002	<.002	<.002
Butylate	21	4.8	0.0	<.002	<.002	<.002	.005
Carbaryl	21	0.0	0.0	<.003	<.003	<.003	<.003
Carbofuran	21	23.8	0.0	.017	<.003	<.003	.122
Chlorpyrifos	21	4.8	0.0	.005	<.004	<.004	.059
cis-Permethrin	21	0.0	--	<.005	<.005	<.005	<.005
Cyanazine	21	100	14.3	1.32	.096	.019	14
Cyanazine-amide	20	55.0	--	.49	.10	<.05	4.5
Dacthal	21	0.0	--	<.002	<.002	<.002	<.002
Deethylatrazine	19	100	--	.320	.140	.06	1.4
Deisopropylatrazine	19	94.7	--	.20	.11	<.05	.70
Diazinon	21	4.8	0.0	<.002	<.002	<.002	.004
Dieldrin	21	9.5	0.0	<.001	<.001	<.001	.006
Disulfoton	21	0.0	0.0	<.017	<.017	<.017	<.017
EPTC	21	19.0	--	<.002	<.002	<.002	0.005

Appendix 2. Statistical summary of pesticides and pesticide degradates at the basic-fixed sampling sites in the Eastern Iowa Basins, 1996–98—Continued

[<, less than indicated detection level; MCL, U.S. Environmental Protection Agency maximum contaminant level; --, MCL not established; * includes estimated concentrations less than the method reporting limit]

Constituent	Number of samples	Detection rate, in percent	Percentage of samples exceeding MCL	Concentration, in micrograms per liter			
				Mean	Median	Minimum	Maximum
Ethalfuralin	21	0.0	--	<.004	<.004	<.004	<.004
Skunk River at Augusta, Iowa (site 12, fig. 1, table 2)—Continued							
Ethoprophos	21	0.0	--	<.003	<.003	<.003	<.003
Fonofos	21	4.8	0.0	<.003	<.003	<.003	.003
Hydroxyatrazine	19	57.9	--	.42	.22	<.20	1.1
Lindane	21	4.8	0.0	<.004	<.004	<.004	.005
Linuron	21	0.0	--	<.002	<.002	<.002	<.002
Malathion	21	0.0	0.0	<.005	<.005	<.005	<.005
Metolachlor	21	100	0.0	1.27	0.214	0.057	9.61
Metolachlor ESA	20	100	--	2.6	2.5	.81	4.7
Metolachlor OA	19	89.5	--	.74	.59	<.20	1.9
Metribuzin	21	28.6	0.0	.010	<.004	<.004	.071
Molinate	21	0.0	--	<.004	<.004	<.004	<.004
Napropamide	21	0.0	--	<.003	<.003	<.003	<.003
p,p'-DDE	21	0.0	0.0	<.006	<.006	<.006	<.006
Parathion	21	0.0	--	<.004	<.004	<.004	<.004
Parathion-methyl	21	0.0	0.0	<.006	<.006	<.006	<.006
Pebulate	21	0.0	--	<.004	<.004	<.004	<.004
Pendimethalin	21	14.3	--	.006	<.004	<.004	.045
Phorate	21	0.0	--	<.002	<.002	<.002	<.002
*Prometon	21	90.5	0.0	.015	.011	<.009	.068
Propachlor	21	4.8	0.0	<.007	<.007	<.007	.021
Propanil	21	0.0	--	<.004	<.004	<.004	<.004
Propargite	21	0.0	--	<.013	<.013	<.013	<.013
Propyzamide	21	0.0	0.0	<.003	<.003	<.003	<.003
Simazine	21	52.4	0.0	.013	.005	<.005	.079
Tebuthiuron	21	28.6	0.0	<.010	<.010	<.010	.035
Terbacil	21	0.0	0.0	<.007	<.007	<.007	<.007
Terbufos	21	0.0	0.0	<.013	<.013	<.013	<.013
Thiobencarb	21	0.0	--	<.002	<.002	<.002	<.002
Triallate	21	0.0	--	<.001	<.001	<.001	<.001
Trifluralin	21	9.5	0.0	<.002	<.002	<.002	0.006